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ART. XI.—*On some phenomena of Binocular Vision;* by JOSEPH LECONTE, Prof. Chem. and Geol. in University of South Carolina.

[Continued from page 77.]

II. *Rotation of the eye on the optic axis.*

NEARLY all the experiments described in this paper had already been made and the results obtained, when my attention was called to Helmholtz's Croonian lecture "On the normal motions of the eye in relation to binocular vision."* From this lecture I received some useful hints, as to the best method of experimenting on this subject, which have been of great service to me, and have made my results much more satisfactory, without, however, materially modifying them. As these results differ very greatly and fundamentally from those of Helmholtz, I repeated the experiments daily for many weeks, modifying them in every conceivable way, to avoid the possibility of error. I am perfectly sure, therefore, that the results are true for my own eyes, and as far as I have been able to have them verified, they are true also for most other normal eyes. Unfortunately, however, the difficulty of verification for other eyes is very great. Many of these experiments which I find perfectly easy are almost impossible for most persons.

Helmholtz's lecture, I suppose, is the most authoritative statement which we have of the present condition of science on

* Proc. Roy. Soc., April, 1864, vol. xiii, p. 186.

the subjects of the motions of the eye and of the Horopter. It seems to be an abstract of more extended researches which I have not seen. On this account it is obscure in some parts; yet I think I cannot be mistaken in his general results. In order to make myself clear, whether in discussing Helmholtz's results or in describing my own experiments, I find it necessary to define the terms I shall most frequently use. The position of the eye when the optic axes are parallel and at right angles to the vertical line of the face, as when with head erect we look at a point on a distant horizon, is called by Helmholtz the *primary direction of the eye*, and the visual line in this case is the *primary direction of the visual line*. All other directions are called *secondary directions*. A plane which passes through the visual line is called a *meridian plane of the eye*, and the intersection of such a plane with the retina we will call a *meridian of the eye*. The *vertical line of demarkation* is that meridian of the eye upon which the image of an apparently vertical line falls when we look directly at the line, and which therefore divides the retina into two equal halves containing corresponding points in the two eyes. The *horizontal line of demarkation* is that meridian of the eye upon which under similar circumstances the image of an apparently horizontal line falls. The plane which passes through the two visual lines we will call the *visual plane*, and that visual plane which is at right angles to the line of the face the *primary visual plane*. The line joining the root of the nose and the point of sight, and which therefore bisects the angle of optic convergence, we will call the *median line of sight*.

Now Helmholtz gives as the law controlling all the movements of the eye the following, viz: that when the eye turns from its primary to any secondary position, *it turns "on a fixed axis which is normal both to the primary and to the secondary visual line."* In other words, the eye may turn on any axis at right angles to the optic axis, but *does not rotate about the optic axis*. Again he states that "vertical and horizontal lines keep their vertical or horizontal position in the field of vision when the eye is moved from its primary direction vertically or horizontally." This law had been previously stated by Listing but without proof; Helmholtz claims to have established it by experiment. His method is very ingenious. It is well known that if we look for some time at a bright object, and then turn the eye upon a comparatively obscure field, a spectrum having the form of the object will be seen. As such spectra are the result of a temporary modification of the retina itself, they must follow the motions of the eye with the greatest exactness. If therefore the bright object be a *line*, then if

there be any rotation of the eye on the optic axis, in turning the eye in various directions the linear spectrum ought to incline to one side or the other. Suppose, then, the object be a bright red vertical line on a gray wall at the exact height of the eye: Helmholtz finds that on gazing at the bright line with one eye, taking care that the eye shall have its primary direction, and then turning the eye in a horizontal plane to the right or left, *the spectrum retains perfectly its verticality.* "I found," he says, "the results of these experiments in complete agreement with the law of Listing." For the ingenious device of Helmholtz for getting the primary position of the eye we must refer the reader to his lecture. I have tried Helmholtz's experiments with similar results. Nevertheless, I believe it may be demonstrated that though rotation of the eye does not take place under the circumstances of these experiments, yet it does so under other circumstances not touched by them; and that in a manner which deeply affects the question of the Horopter. The law of Listing is doubtless true or nearly true when the eyes move together parallel to each other, but is far from being true in strong convergence. The experiments which follow prove beyond a doubt that in my own case and in most other cases tried, *the eyes in convergence rotate on the optic axes outward, and that the amount of rotation increases with the degree of convergence.* Meissner* has attempted to determine experimentally the position of the Horopter, and from the position thus determined he *infers* the rotation of the eyes; my experiments prove *directly* the rotation of the eyes, and from this as well as from direct experiment I hope to establish the position of the Horopter.

Helmholtz, it is true, admits some degree of rotation of the eye on the optic axis, particularly when the eye makes wide excursions in the field of view; but that he does not regard this as sufficient to interfere seriously with the law of Listing is evident from the form of the Horopter which he deduces. Moreover, according to Helmholtz, these slight rotations are controlled by the law of Donders, viz: "*that the eye returns always into the same position when the visual line is brought into the same direction.*" He regards this law as rigorously exact. "Every position of the visual line," he says, "is connected with a determined and constant degree of rotation." But the experiments about to be described prove that under certain circumstances the law of Donders, too, is far from being true.

We have already stated (p. 73) that when the squares of the ruled diagram (fig. 5) are combined by converging the

* Bib. Un. Archiv. des Scien., II, vol. iii, p. 160.

optic axes, if the amount of convergence be great, the horizontal lines of the two images are distinctly observed to cross each

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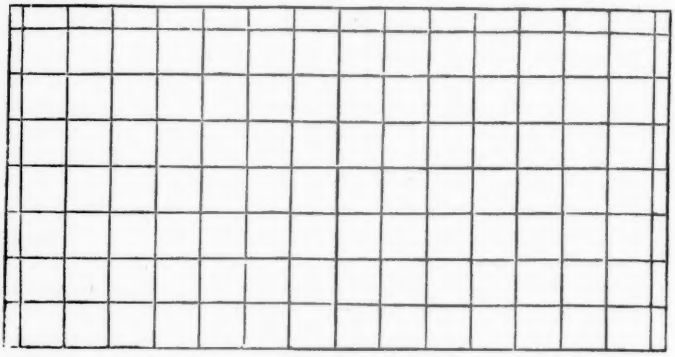

other at small angle. After my attention was once directed to this fact, I could see slight crossing of the horizontals for every degree of convergence, but the verticals seemed to coalesce perfectly. By placing, however, both the diagram and the head perfectly perpendicular, looking straight forward at a point exactly at the same height as the eyes, the visual plane therefore in the primary position, and then slowly increasing or decreasing the convergence of the optic axes, so that the vertical lines of the two images *passed slowly over one another*, it was plainly seen that the verticals of the two images were not parallel, but crossed each other at small angle.

This my original diagram, however, is not well adapted to experiments on this subject for two reasons: 1. It is difficult to distinguish the image of one eye from that of the other. 2. It is difficult to control perfectly the convergence of the eyes. When the vertical lines approach each other, they, as it were, leap and cling together as a single line, even though they really cross at considerable angle; the really crossing lines, by a well known law of stereoscopic combination, being seen as a single line inclined to the visual plane. I therefore constructed a similar diagram, one-half of which consisted of black lines on a white ground and the other half of white lines on a black ground. It is convenient also to have two small circles, one on each half and similarly situated (fig. 6). If I place such a diagram perfectly perpendicularly before me, with the head perfectly erect and the eyes at precisely the same height as the small circles, and then stereoscopically combine the circles by crossing the eyes, I distinctly see the white and

black lines, both vertical and horizontal, crossing one another at small angle, as if the images of both eyes had rotated on

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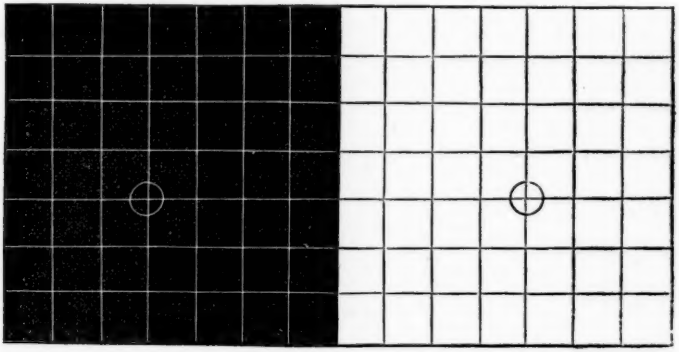

the visual line in opposite directions. This angle of crossing increases as the plane of the diagram is brought nearer and decreases as the diagram is carried farther from the eyes. Or these different angles of crossing may be obtained without moving the diagram or the head, by converging the eyes more and more and causing the white and black vertical lines to pass successively over each other. This is more easily done if there are several small circles on each half, similarly situated but at different distances from each other. In this diagram, the lines being of different colors do not stereoscopically combine easily—they do not cling together as in the other case. Their approach toward or recession from one another and the angle which they make with one another may be marked with the utmost exactness. Nor is there any danger of confounding the two images. For since the eyes are crossed we know that the *white lines* belong to the *right eye* and the *black lines* to the *left eye*, we can therefore determine the direction in which each image rotates. I find always that the black lines or the *image of the left* eye rotates to the right ↷ and the white lines or the *image of the right* eye rotates to the left ↶. Now as the image always moves in a direction contrary to the motion of the eye (differing in this respect from spectra), this indicates *a rotation of both eyes on the optic axes outward* ↶↷.

To test this question still farther I constructed another diagram with the horizontal lines continuous across but the verticals not perfectly vertical, the upper ends of those of the right half inclining to the left and those of the left half to the right

by about 1° 20′ (fig. 7). On bringing the circles together I found that at a certain distance of the diagram—but only at a

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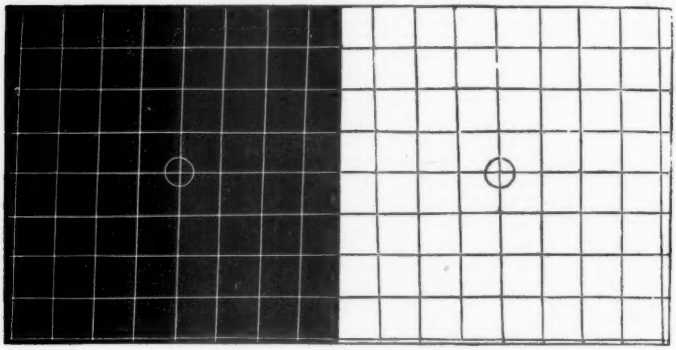

certain distance depending upon the interval between the circles—the *verticals coalesced perfectly;* the horizontals, however, as might be expected, still crossed at a small angle, and in the same direction as before, viz: the whites or right eye image thus ／ and the blacks or left eye image thus ＼, indicating in this case also rotation of each eye outward. *Beyond* the proper distance the verticals approach but do not attain parallelism; *within* the proper distance they cross in a direction contrary to that in the diagram. When the circles are ten inches apart, the proper distance is nearly three feet and the image therefore about seven inches from the eyes.

Helmholtz has a diagram similar in all respects to my own except turned upside down, in which, he states, both verticals and horizontals coincide perfectly when the circles are combined. Our own figure (fig. 7) turned upside down will answer for Prof. Helmholtz's. We quote his own words: "The horizontal lines are parts of the same straight line; the vertical lines are not perfectly vertical. The upper end of those of the right figure are inclined to the *right* and those of the left figure to the left by about $1\frac{1}{3}$ degrees." But his experience differs from our own in a most unaccountable manner. He says: "Now combine the two sides stereoscopically, *either by squinting or by a stereoscope*, and you will see that the white lines of the one coincide with the black lines of the other, as soon as the centers of both figures coincide, although the vertical lines of the two figures are not parallel to each other." He accounts for this, not by rotation of the eyes but by *the*

principle of the difference between real and apparent verticality. The ignorance of this principle he believes has vitiated the results of all previous observers. He illustrates this principle thus: "When you draw on paper a horizontal line, and another line crossing it exactly at right angles, the right superior angle will appear to your right eye too great and to your left eye too small; the other angles show corresponding deviations. To have an apparently right angle, you must make the vertical line incline by an angle of about $1\frac{1}{4}$ degrees for it to appear really vertical. We must distinguish therefore between the *really* vertical lines and the *apparently* vertical lines in the field of view." "Now look alternately with the right and the left eye at these figures (fig. 7 turned upside down). You will find that the angles of the right figure appear to the right eye equal to right angles, and those of the left figure so appear to the left eye; but the angles of the left figure appear to the right eye to deviate much from a right angle, as also do those of the right figure to the left eye." Prof. Helmholtz therefore believes that the perfect stereoscopic coincidence of the vertical lines of his diagram is the result of this principle. "Therefore," he says, "not the really vertical meridians of the two fields correspond as has been hitherto supposed, but the apparently vertical meridians. On the contrary, the horizontal meridians really correspond at least for normal eyes which are not fatigued."

On this principle Prof. Helmholtz builds his whole theory of the Horopter. But that this principle cannot account for the phenomena he observes I think can be proved. In the first place, I find that if there be any distinction between real and apparent verticality for my eyes, the difference is too small to be detected by the simple observation of lines drawn at right angles with each other. For my own eyes really vertical lines are also apparently vertical, and lines inclined $1\frac{1}{4}$ from verticality are not at all apparently vertical. I have tried several other normal eyes with the same result. But leaving this aside: in the second place, it is by no means indifferent whether the two halves be combined by a "*stereoscope or by squinting.*" If they are combined by a stereoscope as stereoscopes are usually constructed, the right half is looked at by the right eye and the left half by the left eye, so that the point of sight and the plane of combination is *beyond the diagram;* coincidence in this case, therefore, would be a true illustration of Prof. Helmholtz's principle. But if they are combined by squinting, the eyes are crossed, and therefore *the right eye is looking at the left half and the left eye at the right half* of the diagram, and therefore in Prof. Helmholtz's own

words, the verticals should "deviate much from a right angle," viz: $2\frac{1}{2}$ degrees. I have tried many eyes and I have yet found *none* in which the coincidence of the verticals of Prof. Helmholtz's diagram was perfect when combined by means of a stereoscope, i. e., beyond the diagram; but I have found *one* person to whom the coincidence seemed to be perfect when the combination was made by squinting.

It is evident, then, that Prof. Helmholtz's principle cannot explain the stereoscopic coincidence by squinting in his own experiment. I myself believe that if the coincidence takes place only by squinting (as in the case mentioned above), it can only be explained by rotation of the eyes *inward*. It is true that in this case the horizontals ought to cross also; but Prof. Helmholtz himself admits that such is sometimes the fact, but attributes it to fatigue. "After keeping the eyes," he says, "a long time looking at a near object, as in reading or writing, I have found that the horizontal lines crossed each other; but they became parallel again when I had looked for some time at a distant object."

On reading Prof. Helmholtz's lecture and finding his results so different from my own, I immediately tried his figure by squinting, but found the verticals cross one another at an inclination much greater than in the diagram itself, while the horizontals also crossed but at a less angle. On turning the figure upside down, however, the verticals coincided perfectly when the proper distance was obtained, though the horizontals crossed as before. All these phenomena are easily explained by rotation of the eyes *outward*. To test the question still more thoroughly, I then constructed other diagrams in which both verticals and horizontals were inclined so as to make an angle of $1\frac{1}{4}$ degrees with the true vertical and the true horizontal (fig. 8) and therefore perfect squares with one another. At the proper distance, when the small circles were brought together, *the coincidence of both verticals and horizontals seemed to be perfect.* When the plane of the diagram was too near or too far, all the lines crossed, in the one case in one direction and in the other case in the other direction. I then constructed still other diagrams, in which the inclination of the lines with the true vertical and the true horizontal were 40 minutes, $2\frac{1}{2}$ degrees and 5 degrees. In all cases I brought the lines in coincidence, but of course by different degrees of convergence. In the last the optic convergence necessary was extreme, and the strain on the eyes considerable; but in the other cases there was not the slightest difficulty or strain. Recollecting, however, that Prof. Helmholtz supposed that the change of position of the horizontals might be the result of

fatigue, I tried repeatedly after long rest but always the phenomena were precisely the same. In the diagram in which the

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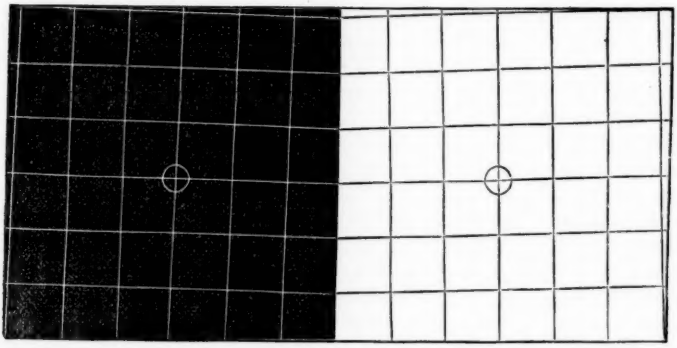

inclination of the lines was five degrees I observed, however, that a *greater degree of convergence was necessary to bring the horizontals in coincidence than to bring the verticals into coincidence.* The difference in the distance of the diagram in the two cases was about two inches and the difference in the distance of the point of sight was about one-half inch. I cannot explain this except by supposing that the form of the optic globe was changed by the excessive action of the muscles.

I can conceive of no possible source of fallacy in these experiments. From long practice they have become almost as easy to me as any ordinary act of vision. They do not now fatigue my eyes in the slightest degree. I see the lines of the two images, which I bring together just as plainly as if they were black and white threads. While watching them I control their motions almost as perfectly as if I was sliding with my hands two frames with white and black threads stretched across them. There is not the shadow of a doubt, therefore, that in my own case the eyes in convergence rotate slightly outward, and that the amount of rotation increases with the degree of convergence.

I next proceeded to determine the amount of rotation for different distances of the point of sight. In the diagram in which the inclination of the lines was 5 degrees, the distance of the image was only 2 to 2½ inches; for the lines inclined 2½ degrees, the distance of the image was 4 inches; for lines inclined 1¼ degrees, the distance was 7 inches; and for 40 minutes, the distance was about 12 to 14 inches. I am able, by great strain, to obliterate or nearly obliterate the common field of view of the two eyes. In this case of course the eyes

both look at the root of the nose. In this extreme convergence I find that lines coincide which make with each other an angle of 22 degrees or 11 degrees with the vertical. This would seem, therefore, the extreme rotation for my eyes. The distance of the image in this case is nearly at the root of the nose.

If, however, in extreme convergence, rotation on the optic axes takes place to the extent of 11°, this rotation ought to be detectable by means of ocular spectra or even by direct observation of the eye itself. I determined to try these also. My method of experimenting with ocular spectra is as follows: Standing in a somewhat obscure room, I gaze with the left eye (the other being shut) at a vertical crevice in a closed window until a distinct spectrum is obtained. Placing myself now opposite a vertical line on the wall of the room, with my right side toward the wall, I turn my head until my left eye II (fig. 9), looking across the root of my nose *n*, can see the vertical

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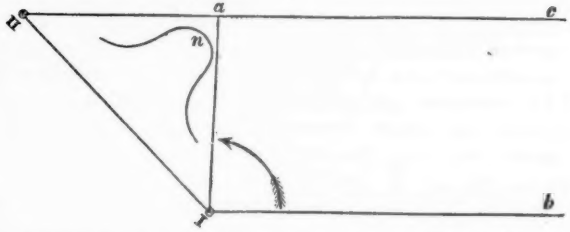

line. I now gaze at a point very near the vertical line, and by inclining my head to one side or the other, bring the spectrum exactly parallel to the vertical line. In this position, if the wall be at some distance from the observer, the axes of the eyes may be regarded as nearly parallel as II*c* I*b*. I now, by a voluntary effort, bring the point of sight along the line II*c* nearer and nearer, until it reaches *a* near the root of the nose. In doing so the spectrum is always seen to incline to the left thus |. On relaxing the convergence and looking again at the wall, the spectrum retains its inclined position for an appreciable time and then gradually recovers its original verticality. In similar experiments with the right eye the spectrum is always seen to incline to the right thus |.

I next tried direct observation of the eye itself. As I could not find any one with the necessary control over the eyes, I was compelled to make myself the subject of this observation. While therefore, with the right eye shut, I gaze with the left

eye across the root of the nose on vacancy, or on a distant object as in the figure (fig. 9), an observer conveniently placed near the visual line carefully examines the iris of my eye so as to recognize the position of the radiating lines. When now, without changing the position of the visual line of the left eye, I turn the right eye inward, as in the previous experiment, until the point of sight is at *a*, the globe of the left eye is distinctly seen to rotate outward. I got four different persons to make this observation upon my eye, and the testimony of all was the same.

I had proceeded thus far in my experiments when I was led to reflect farther upon the phenomena presented by the diagram in which the lines were highly inclined. In this diagram, it will be remembered, the verticals were combined with more facility than the horizontals. I now repeated all my experiments with more care and with especial reference to this point. As I expected I found the same true for all the diagrams, but the difference was so small that it had escaped detection. This led me to suspect that there might be some truth in Prof. Helmholtz's principle of real and apparent vertical. I therefore constructed many other diagrams to test this point. I constructed first a diagram exactly like figure 6, except that the circles were the same distance apart as my eyes, viz: $2\frac{1}{2}$ inches. On placing this diagram before me and gazing on vacancy, the eyes therefore in their primary position, the circles were brought together. In this experiment the *verticals came together parallel.* I sometimes thought there was a scarcely perceptible inclination in the direction required by Helmholtz's principle, viz: thus /\. If any such inclination really existed, it could not have been more than 10′ for each line with the vertical, or 20′ with one another; for this angle I can distinctly detect under these circumstances. I next constructed a diagram like Prof. Helmholtz's, except that the outward inclination of the verticals was only 40′ instead of $1\frac{1}{4}°$. On combining the two halves of this diagram by means of a stereoscope, there really seemed to be perfect coincidence of both verticals and horizontals; but I soon found by trying several, that stereoscopes differ much in this respect. I therefore discarded them as unreliable. On combining the same diagram with the naked eye in the manner of a stereoscope, i. e., beyond the plane of the diagram, the verticals coincided perfectly when the point of sight was about twelve inches distant, but the horizontals very perceptibly crossed, though certainly, I think, at an angle less than 40′—it seemed about 20′. On combining the two halves by squinting (of course turning the diagram upside down), I

found the result precisely the same when the point of sight was at the same distance, viz: twelve inches. In the next diagram which I constructed the verticals inclined $1\frac{1}{4}$ degrees and the horizontals 50 minutes, the difference being therefore 25 minutes. In this case both seemed to combine perfectly when the point of sight was distant $7\frac{1}{2}$ inches. The next diagram tried had the verticals inclined 5° and the horizontals 3° 45′, the difference being $1\frac{1}{4}$ degrees. In this case both verticals and horizontals combined perfectly at the distance of 2·2 inches. I then tried one in which the verticals inclined 10°. In this case I could not make perfect coincidence of both verticals and horizontals until the difference of inclination was made as great as 5°. The diagram used is shown reduced in the figure (fig. 10). The point of sight in this

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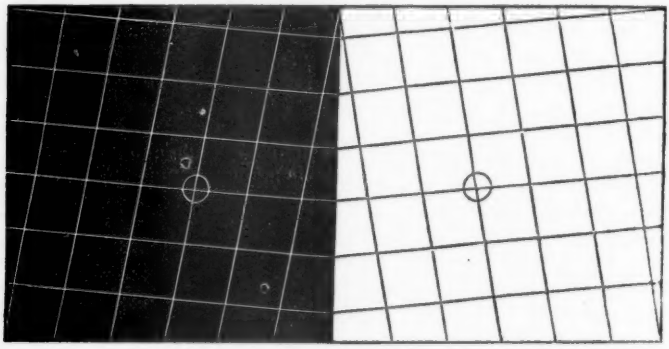


experiment was only $1\frac{1}{4}$ inch from the line joining the optic centers, or about one-quarter inch from the root of the nose.

I attribute these phenomena to a slight distortion of the ocular globe under the action of the oblique muscles—a distortion which increases with the degree of optic convergence. We will refer to this again.

In all the experiments described above the greatest care was taken that the visual plane should be in the primary direction, i. e., at right angles to the line of the face, and especially that the median line of sight should be at right angles to the plane of the diagram. I now wished to try the effect of turning the visual plane upward and downward. Meissner, from his experiments on the position of the Horopter, had arrived at the conclusion that the rotation of the eye was zero, whatever be the degree of convergence, when the visual plane was inclined downward 45° from its primary position, and that the rotation increased as the plane was elevated toward the eyebrows. I

was anxious to test this result. The plane of the diagram still remaining vertical I now turned the face upward (taking care, however, that the eyes should still be on an exact level with the circles of the diagram), until the eyes looked in the direction of the point of the nose. In this position, on stereoscopically combining the small circles, the lines, both vertical and horizontal, in all cases *maintained their true position :* i. e., in the diagram with parallel lines (fig. 6), the coincidence of all the lines was perfect, in the diagram with inclined verticals (fig. 7), the horizontals coalesced perfectly and the verticals crossed at their true angle of inclination, while in the diagram with the verticals and horizontals both inclined (fig. 8), both the verticals and horizontals crossed at their true angle of inclination. I tried the same experiment for various distances and therefore various degrees of optic convergence, but always with the same result. *There is,* therefore, *no rotation* of my eyes *when the plane of vision is inclined* 45° *downward.* In continuing the inclination still farther downward I observed a decided rotation of the eyes in the contrary direction, i. e., *inward.* As the eyes are raised from the position, 45° downward, the rotation increases until the visual plane is again in its primary direction. When the visual plane is raised above this, however, I do not find the rotation to increase as stated by Meissner, except in cases of extreme convergence, but rather to decrease again, although it does not again become zero.* In strong convergence, however, as for instance, when the point of sight is less than seven inches distant, the rotation continues to increase as stated by Meissner.

In all these experiments, in order to detect the true rotation, it is absolutely necessary that the median line of sight should be exactly at right angles with the plane of the diagram. The least error in this respect will cause *perspective convergence* of the parallel verticals, or increase or decrease of the angle of inclination of the inclined verticals. With the diagram three feet distant, if my eyes look one inch above or below their true level, on combining the two halves of the diagram I can detect the perspective convergence, upward or downward, with the greatest ease. In all cases, also, but particularly when the convergence is very strong, it is necessary to fix the attention on that horizontal which passes through the small circle, for those above and below converge by perspective.

* More recent experiments, just concluded. have convinced me that in my own eyes, if the convergence is very slight, the outward rotation *does* reach zero and may even be converted into an *inward* rotation. The reason is, that when my eyes are parallel or nearly so, elevation of the visual plane causes *inward* rotation. In some other eyes, however, I have found that elevation of the visual plane when the eyes are parallel causes outward rotation as stated by Meissner. In these cases, therefore, Meissner's results on this point are entirely true.

In these experiments the size of the diagrams is of little importance. I have used them of every size from 5 by 10 inches to 15 by 30 inches.

My next desire was to determine how far these results were general for normal eyes. The great difficulty was to find any one who was able to repeat the experiments. Nevertheless, I have found four young persons with normal eyes who, with some practice, have succeeded in all except the most difficult of them. *Their results agreed perfectly with my own.* In a fifth case, however, in which great difficulty was experienced and the results were uncertain, I was led to believe that the eyes in convergence rotated *inward.* It is not improbable, therefore, that normal eyes differ in this respect.

We believe, therefore, that we are justified in the conclusion that when the eye is in its primary position and therefore passive, the vertical line of demarkation coincides with the vertical meridian and the horizontal line of demarkation with the horizontal meridian of the eye, and therefore these two lines of demarkation are at right angles to each other. But as soon as the eyes begin to converge, the oblique muscles (particularly the inferior oblique) begin to act, rotating the eye on the optic axis and slightly distorting its form; so that the vertical line of demarkation is now not only no longer coincident with the vertical meridian but also no longer at right angles to the horizontal line of demarkation. Both the rotation and the change in the relation of the two lines of demarkation increases with the degree of optic convergence. It is possible that the frequent action of the muscles distorting the globe of the eye may leave some permanent impress upon the form of the globe, so that even in a passive state the vertical line of demarkation does not coincide perfectly with the vertical meridian. If so, then to that extent Helmholtz's principle of real and apparent vertical in the primary position of the eye would be true. Or to express it differently: we have seen that the inclination of the vertical upon the horizontal line of demarkation decreases as the point of sight recedes; at $1\frac{1}{4}$ inches it is 5°, at 2·2 inches it is $1\frac{1}{4}$°, at 7·5 inches it is 25′, and at 12 inches 20′. It is possible that even when the point of sight recedes to infinite distance and the horizontal line of demarkation becomes coincident with the horizontal meridian, the vertical line of demarkation may still make a small angle with the vertical meridian. If so, this angle is the difference between the real and apparent vertical spoken of by Prof. Helmholtz. We do not yet admit this as probable, however, for the natural position in which all lines at all distances combine when the visual plane is inclined 45° downward seems inconsistent with this idea.

The decrease of the rotation of the eye when the visual plane is inclined downward and its increase when the visual plane is inclined upward, seems to be the result of the relative power of the two oblique muscles. Ordinarily the inferior oblique is the stronger and the rotation is therefore outward, but as the visual plane is inclined downward, the action of the two become more and more nearly equal, until at 45° they balance each other and there is no rotation. Below 45° the action of the superior oblique predominates and the eye therefore rotates inward. In turning the visual plane upward and converging strongly, the action of the inferior oblique predominates more and more.

It will be observed that the rotation of the eye which we have demonstrated necessitates, in optic convergence, a difference between the real and apparent vertical; but our views differ entirely from those of Prof. Helmholtz's in the following respects: 1. Prof. Helmholtz admits only a difference between real and apparent *vertical*; we have shown a difference between the real and apparent horizontal as well as the real and apparent vertical. 2. Prof. Helmholtz's difference is a constant one, viz, 1¼°; ours varies from 11° to 20′ and probably to zero. 3. According to Prof. Helmholtz the relation of the apparent vertical to the apparent horizontal is a constant one, viz: an angle of about 88¾°; our experiments prove that this relation varies to the extent of 5°.

It is certain, therefore, that the law of Listing is far from being true in strong convergence. Evidently the reason is that in convergence muscles are used which are not used in simply turning the eyes from side to side, as in the experiments used by Helmholtz to prove this law (p. 155). That different muscles are used in strong convergence is easily shown as follows: It is easy to turn either eye inward until it looks in the direction of the root of the nose, provided the other eye moves parallel with it, i. e., outward; but it is almost impossible to turn both eyes at the same time so as to look at this point. Great strain is experienced in producing convergence even much short of this. The eyes are turned from side to side, parallel to each other, by means of the interior and exterior recti muscles, while in convergence the oblique muscles are also used. For this reason Prof. Helmholtz's experiments on spectra do not apply to convergence.

The law of Donders is equally untrue for strong convergence. This law asserts that the position of the eye is rigorously constant for every position of the visual line. But in the experiment represented by figure 9 the eye II, *although the direction of its visual line is unchanged, rotates on its axis* when the

visual line of the other eye is turned from the direction I*b* to the direction I*a*.

The reason is, that as I. turns toward *a* the oblique muscles in both eyes begin to act. It is probable that the action of the oblique muscles and therefore the rotation of the eye, is *consensual with the two adjustments and with the contraction of the pupil;* and it is well known that under the circumstances represented by the figure, the pupil of the eye II would contract also, although the direction of the visual line is unchanged.

III. *The Horopter.*

If we look intently at any point the visual lines converge and meet at that point. Its image is therefore impressed on exactly corresponding points of the two retinæ, viz: on the central spot of each. A small object at this point is therefore seen single. We have called this point the *point of sight.* All objects beyond or on this side of the point of sight are seen double, for their images do not fall on corresponding points of the two retinæ. But objects above or below, or to one side or the other of the point of sight, may possibly be seen single also. *The sum of all the points which are seen single,* while the point of sight remains unchanged, *is called the Horopter.* Or it may be expressed differently thus: Each eye projects its retinal images outward into space and therefore has its own field of view crowded with its own images. When we look at any object, we bring the two external images of that object in coincidence at the point of sight. Now the point of sight, together with all other corresponding points of the two fields of view which coalesce at that moment, constitute the Horopter. Of course the image of all points lying in the Horopter fall on *corresponding points* of the retina.

Is the Horopter a surface or is it a line? In either case what is its form and position? These questions have tasked the ingenuity of physicists, mathematicians and physiologists. If the position of identical points of the retinæ under all circumstances was known, then the question of the form of the Horopter would become a purely mathematical one. But the position of identical points evidently depends upon the laws of ocular motion. It is evident, therefore, that it is only on an experimental basis that a true theory of the Horopter can be constructed; and yet the experimental investigation as usually conducted is very unsatisfactory, on account of the indistinctness of vision when the object is at any considerable distance from the point of sight in any direction.

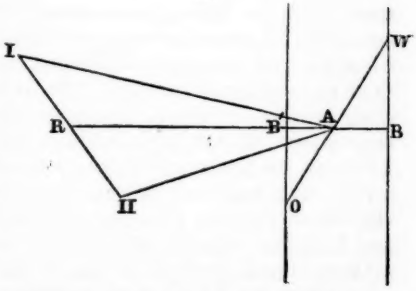
The most diverse views have, therefore, been held as to the

nature and form of the Horopter. Aguilonius, the inventor of the name, believed it to be a plane passing through the point of sight and perpendicular to the median line of sight. Others have believed it to be the surface of a sphere passing through the point of sight and the optic centers; others, a torus formed by the revolution of a circle passing through the point of sight and the optic centers, on a line joining the optic centers. The subject has been investigated with great acuteness by P. Prévost, A. Prévost, J. Muller, G. Meissner, E. Claparède,* and lastly by Helmholtz.† A. Prévost determines in it, as he supposes, a circle passing through the optic centers and the point of sight, which he calls the "*horopteric circle*," and a straight line passing through the point of sight at right angles to the visual plane, which he calls the "*horopteric vertical.*"

Until the investigations of Meissner almost all attempts to determine the form of the Horopter have been by mathematical calculations, based upon the doctrine of identical points and assuming the law of Listing. Meissner attempts the same question experimentally. We condense the following account of his admirable investigations from Claparède's memoir of this subject‡ already referred to:

Let R (fig. 11) be an observer and I II his two eyes, A the point of sight, B an object beyond and B′ an object nearer than the point of sight, but all in the same line, joining the root of the nose and the point of sight. Of course, both B and B′ will be seen double. If, now, while the sight is still fixed upon A, B be elevated, its two images, according to Meissner, will approach, until at some point, W, they coalesce. If, on the contrary, B be depressed, its images separate more and more. If, now, B′ be elevated, its images separate, but if it be depressed, its images approach and coalesce at O. The line WAO is, therefore, the Horopter or line of single vision. It is not at right angles but inclined to the plane of vision. Again, according to Meissner, if instead of points we have vertical lines like threads WB and OB′ (fig. 11), then OB′ will

11.



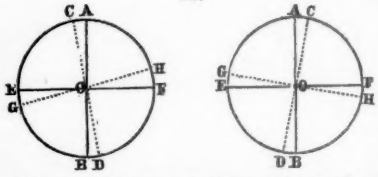
* Bib. Un. Archiv. des Scien., II, vol. iii, p. 138 and 225.

† Proc. Roy. Soc., Apr., 1864. ‡ Bib. Un. Arch. des Scien., vol. iii, p. 138.

double at B′, the images being crossed, and approach one another and meet at O, in other words, will appear thus: while BW will also double at B but not cross (i. e., each image will have the same name as the eye), and will be seen to converge and meet at W thus . Lastly, if the vertical line pass through the point of sight A, the images will cross one another like an X.

Meissner accounts for these phenomena by supposing that, in converging the optic axis, the eyes rotate on the optic axis outward so that the vertical lines of demarkation CD no longer coincide perfectly with the vertical meridians AB (fig. 12,) as they do when the eyes are in the primary direction (the axis parallel) but cross them at a small angle. In the primary direction of the eye the image of a vertical line according to Meissner falls on the vertical line of demarkation CD in both eyes (for these lines then coincide with the vertical meridian) and is therefore seen single. But if the eyes rotate on the optic axes outward then the image of a vertical line still falling on the vertical meridian must cross the line of demarkation in opposite directions in the two eyes and therefore cannot be seen single except at the point of sight, the image of which corresponds to the central point O of the retina of each eye. In order that the image of a line shall fall on the line of demarkation in both eyes and thus be seen single, it must be inclined at a certain angle with the vertical, the lower end being nearer and the upper end farther away. It is moreover evident, upon a little reflection, that when the eye rotates the Horopter cannot be a plane nor a surface of any kind, for objects right and left of the horopteric line must all be doubled by displacement of the horizontal line of demarkation GH (fig. 12,) which therefore no longer coincides with the horizontal meridian EF.

12.



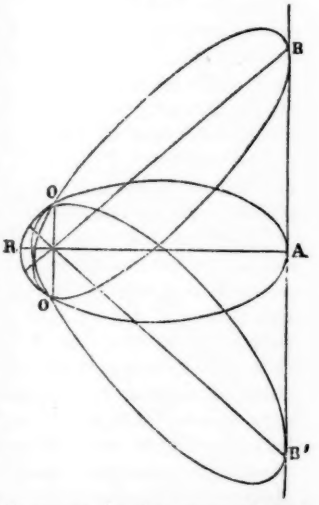
From various experiments made at different distances and with different degrees of inclination of the visual plane upward and downward, Meissner concludes: 1. That looking straight forward at an infinite distance the Horopter is a plane at right angles to the visual lines. 2. That for all other distances, the visual plane remaining the same, the Horopter is a straight line passing through the point of sight and increasing in inclination to the visual plane, as the convergence of the optic axes increases. 3. That in turning the visual plane downward,

the inclination of the horopteric line with that plane becomes less and less, until at 45° downward it becomes perpendicular and therefore the Horopter again expands into a plane at right angles to the median line of sight. 4. That in raising the visual plane upward toward the eyebrows, the inclination of the Horopter to the visual plane increases.

We have given Meissner's investigations more in detail, because by entirely different methods we have confirmed almost all of them.

Claparède by similar experiments fails to confirm the conclusions of Meissner and therefore rejects them. He concludes, partly from his own experiments and partly from calculation, that "the Horopter is a surface of such a form that it contains a straight line perpendicular to the plane of vision and passing through the point of sight, and that every plane passing through the optic centers makes by intersection of this surface, the circumference of a circle." In other words, he believes that the horopter is a surface which contains the horopteric vertical BAB′ (fig. 13) and the horopteric circle OAO of Prévost, and that in addition the surface is further characterized by the fact that, while the point of sight remains at A, the intersection with it of every plane passing through the optic centers OO upward or downward as OBO and OB′O is also a circle. It is evident that as these circles would increase in size upward and downward the Horopter according to Claparède, must be a surface of singular and complex form.

13.



Finally, Helmholtz arrives at results entirely different from all previous observers. He sums up his conclusions as follows:

"When the point of convergence is situated in the middle [vertical] plane of the head, the Horopter is composed of a straight line drawn through the point of convergence [direction not stated but evidently not at right angles to the visual plane, for see below the sentence marked[a]] and a conic section passing through the optic centers and intersecting the straight line."

"When the point of convergence is in the plane which con-

tains the primary visual lines [primary visual plane], the Horopter is a circle going through that point and the optic centers [Prévost's horopteric circle] and a straight line intersecting the circle [where and in what direction not stated]."

"When the point of convergence is situated as well in the middle plane of the head as in the primary visual plane, the Horopter is the circle just described [Prévost's horopteric circle] and a straight line going through that point [direction not stated]."

"There is but one case in which the Horopter is really a plane, viz: when the point of convergence is in the middle plane of the head and at an infinite distance. Then the Horopter is a plane *parallel* to the visual plane and *beneath* it, at a certain distance which depends upon the angle between the *really* and *apparently vertical* meridians, but which is nearly as great as the distance of the feet of the observer from his eyes when he is standing. Therefore, when we look at a point on the horizon, the *Horopter is the ground on which we stand.* "When we look at the ground on which we stand at any point equally distant from both eyes, the Horopter is not a plane, but the straight line which is one of its parts *coincides completely with the horizontal plane on which we stand.*"

These conclusions of Helmholtz are the result of refined mathematical calculations *based entirely upon the supposed constant difference between the real and apparent vertical.* If this principle be true for all normal eyes, then it is probable that Helmholtz's conclusions in regard to the form and position of the Horopter are also true for those cases in which the point of sight is at considerable distance and in which, therefore, the rotation of the eye is very small. I am not able to test all of Prof. Helmholtz's conclusions by calculations based upon this principle, but I easily see that the position of the Horopter lying along the ground is the necessary consequence of a difference of $1\frac{1}{4}$ degrees between the real and apparent vertical when the eyes are in their primary direction. For if a line be drawn from each pupil downward, making an angle of $2\frac{1}{2}°$ with each other or of $1\frac{1}{4}°$ with the vertical, they would intersect each other at the distance of about five feet below the eyes or about the feet of the observer standing erect. Now if these two lines be placed thus \/ before the observer whose eyes are in the primary direction, it is plain that their stereoscopic combination would be a line lying along the ground to infinite distance. If the difference between the real and apparent vertical be less than $1\frac{1}{4}°$, then the distance below the eyes of the horopteric plane would be greater. We have already shown

that if there be any such difference in our own eyes, it cannot be more than 10′; in this case the horopteric plane would be at least 35–40 feet below the eyes. But Prof. Helmholtz takes no account of rotation of the eyes on the optic axes, which greatly affects the form and position of the Horopter when the point of sight is near; and we believe that it is only when the point of sight is near, that the form and position of the Horopter is of any practical importance in vision, for it is only then that the doubling of images lying out of the Horopter is perceptible.

It has been with much hesitation that I have ventured to criticise the conclusions of so distinguished a physicist. My ability to do so, if well founded, I attribute entirely to a facility in the use of the eyes such as I have never seen equalled in the case of any other person.

Although, I believe, Meissner has arrived at truer results than any one who has yet written on this subject; yet I think his method very unsatisfactory. I have wondered at the skill and patienee which could attain such true results by such imperfect methods. I have tried Meissner's experiments without any satisfactory results, and I confess I commenced these experiments with the conviction that his theory was untenable; but contrary to my expectation his views have been in a great measure confirmed. The difficulty with Meissner's method and in fact with all previous experimental methods, as already stated, is the indistinctness of objects at any considerable distance from the point of sight in any direction. In Meissner's experiment with the three points, B′, A and B (fig. 11), in lowering B′ or elevating B, the indistinctness was so great that I could not tell with certainty whether the images approached each other or not; and in his second experiment with the thread, the obstinate disposition on the part of the eye to see single by stereoscopic combination even when the images cross, interferes seriously with the certainty of the result. But in my experiments, by virtue of the complete dissociation of the axial and focal adjustments, the lines are seen perfectly clearly; and by making them pass each other slowly, their relation to each other may be observed with great exactness.

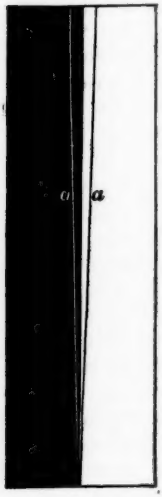
I will now state my own results in regard to the Horopter.

It is evident that if, in convergence, the eyes rotate on the optic axes as my experiments prove, then in this state of the eyes the Horopter cannot be a surface, but a line; and this line cannot be vertical but inclined to the visual plane. Perhaps this requires farther explanation. If the eyes in a state of convergence be fixed on a vertical line, then if the eyes rotate the line must be doubled except at the point of sight. This doubling

is the result of *horizontal* displacement of the two images in opposite directions, and therefore the two images may be brought together by bringing the doubled portion of the vertical line nearer or carrying it farther away. This is done in inclining the line as in fig. 11. But all points to the right and left of the horopteric line are also doubled by rotation, but this doubling is the result of *vertical displacement* of the images; now vertical displacement cannot be remedied by increasing or decreasing the distance, because *the eyes are separated horizontally.* Therefore no form of surface can satisfy the conditions of single vision right and left of the horopteric line. The restriction of the Horopter to a straight line and the inclination of that line to the visual plane are therefore necessary results of rotation on the optic axes. But I have also proved this by direct experiment.

If two lines, one white on black and the other black on white (fig. 14) be drawn at an angle of $1\frac{1}{4}$ degrees with the vertical and therefore $2\frac{1}{2}$ degrees with each other, then by bringing my eyes so near to them at any point *aa* (taking care that the median line of sight shall be perpendicular to the plane of the lines) that the visual lines without crossing shall meet beyond the diagram at the distance of seven inches from the eyes, the two lines are brought in perfect coincidence. If on the contrary the same figure be turned upside down and the eyes be placed a little farther than seven inches, so that the two points *aa* are brought together by crossing the optic axes at the distance of seven inches, then also the lines are brought in perfect coincidence. The accompanying figure (fig. 15) in which OO are the eyes, A the point of sight, *a*H, *a*H and *a*′H′, *a*′H′ are the lines in the two positions, will explain how the stereoscopic combination takes place in each case. The line HAH is the Horopter. This experiment is difficult to perform satisfactorily. When the lines come together it is difficult to determine whether there is real coincidence or not. I have observed, however, that when the coincidence is not perfect the white and black lines seem to run spirally round each other. The best plan is to observe them at the moment of coming together or of separating. I feel quite confident of the reliability of the conclusions reached.

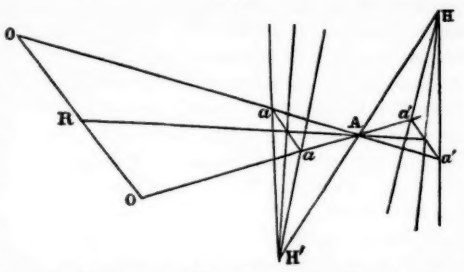
14.



I made many calculations based upon these experiments and on the previous experiments on rotation of the eye, to determine the inclination of the horopteric line for different degrees

of convergence, i. e., for different distances of the point of sight. The results of these calculations were not entirely satisfactory. I had expected from Meissner's results that there would be found a progressive increase as the distance decreased. But I could not be sure from my calculations of any increase or decrease with distance. For all distances the inclination seemed to come out about seven degrees—in some a little less, in some a little more. Beyond three inches there seems to be a slight progressive increase rather than decrease; within three inches the action of the eyes was irregular.

15.



I then adopted another method. I used the diagram of parallel lines (fig. 6,) and inclined it at an angle of exactly 7° from the perpendicular in the supposed direction of the Horopter, and at the distance of 3 feet. In this position the verticals of course all converge by perspective. I then brought together successively the lines 3 inches apart, then those 6 inches apart, then those 9 inches, 12 inches, 15 inches, 18 inches and so on even to the last, which were 30 inches apart: *in each case the lines seemed to come together parallel* or at least the divergence, if any, was so small that I could not be sure about it. Now in this experiment the point of sight varied from 16½ inches to only 2·8 inches in distance, and yet the inclination of the horopteric line seemed to be nearly the same for all, viz: 7°. If there was any difference at all it seemed to be in favor of *greater inclination at greater distance.* This result which I arrived at, though doubtfully by experiment alone, would be the necessary result of any residual difference between the real and apparent vertical, or in other words, any residual inclination of the vertical upon the horizontal line of demarkation of the eye in its primary position, such as Helmholtz maintains and as I have supposed possible. Still it by no means proves the existence of this residual difference.

It must not be supposed, however, because the lines 3 inches, 6 inches, 9 inches, 12 inches, &c., apart, are all brought into coincidence at the same or nearly the same inclination, that therefore the amount of rotation of the eye is the same for all. The perspective convergence of the lines, of course increases with their distance apart, and therefore the rotation of the eye necessary to bring them successively into coincidence

increases also. It is quite possible that the rotation should increase with the optic convergence, and yet the inclination of the horopteric line remain constant or even decrease with the convergence. Whether the inclination of the horopteric line increases or decreases with distance would depend upon the law of increase of rotation with increasing convergence. If it increases with distance then it is possible that when we look at the ground before us the Horopter may be a line lying along the ground, as maintained by Helmholtz.

I next tried the same experiments with the eyes inclined downward 45°. The *lines do not change at all their natural perspective convergence.* In all the experiments made with eyes in this position the inclination of the lines in the image was the same as in the object. I conclude therefore that in this position of the eyes the Horopter is at right-angles to the plane of vision, and since there is no rotation of the eye the Horopter in this position expands *into a surface.* Below this inclination *the Horopter again becomes a line but inclined now the other way, i. e., the upper end toward the observer.* In turning the eyes upward toward the eyebrows, I have found the rotation, except in cases of strong convergence, less than looking straight forward. I conclude therefore that in this position the horopteric line inclines less to the visual plane than it does when the visual plane is in its primary direction.*

The points in which my experiments do not confirm Meissner are—1, the increasing inclination of the horopteric line with increasing convergence. 2, the increasing rotation of the eye as well as inclination of the horopteric line under all circumstances in turning the eye upward. Again, I believe that Meissner is also wrong in supposing that the Horopter is a *plane* when the eyes are depressed 45°. In this position it is a *surface* but not a plane. It is clear that the images of points situated to the right and left of the point of sight and in the same plane with it cannot fall on corresponding points of the two retinæ. As to the form of this surface, I feel myself unequal to the task of its mathematical investigation, and its experimental investigation presents, I believe, insuperable difficulties.

We have seen that the eye in convergence rotates on the optic axis. The question naturally occurs, is this rotation to be regarded in the light of an imperfection of the instrument (of which there are several examples in the structure and mechanism of the eye,) and should the law of Listing be regarded as

* As stated in note on p. 165, eyes certainly differ in this respect. In my own, if convergence be small, the outward rotation decreases with the elevation of the visual plane, becomes zero, and even is converted into an *inward* rotation; the inclination of the Horopter, therefore, decreases, *becomes perpendicular and even inclines the other way.* In some other eyes the outward rotation increases whatever be the convergence; in this case, of course, the inclination of the Horopter increases as stated by Meissner.

the ideal of ocular motion, though an ideal seldom or never realized in nature; or does the rotation of the eye subserve some useful purpose in vision? I believe there is no doubt that the latter view is the correct one, for there seems to be special muscles which are adapted for this rotation and the action of these muscles is consensual with the adjustments of the eye and the contraction of the pupil. This purpose I explain as follows. A general view of objects in an extended field is absolutely necessary to animal life in its highest phases, but an equal distinctness of all objects in this field would only distract the attention. Therefore the eye is so constructed and moved, as to restrict as much as possible both *distinct* vision and *single* vision. Thus as in *monocular vision* the more elaborate structure of the *central spot* of the retina restricts distinct vision to the visual line, and the *focal adjustment* still farther restricts it to a single point in that line; so also in *binocular* vision, *axial adjustment* restricts single vision to the Horopter, while rotation restricts the Horopter to a single line.

Conclusions.

The most important conclusions arrived at in this paper may be briefly summed up as follows.

1. The axial and focal adjustments of the eye are not so inseparably associated as is generally supposed; but on the contrary when distinctness of vision requires it they may be completely dissociated.*

2. In this dissociation, the contraction of the pupil associates itself with the focal in preference to the axial adjustment.

3. In optic convergence there is a rotation of both eyes on optic axes *outward*; and this rotation increases with the degree of convergence.

4. In inclining the visual plane downward the rotation of the eyes for the same degree of convergence decreases, until when the visual plane is inclined 45° downward the rotation becomes zero for all degrees of convergence. Below the inclination of 45° the rotation is *inward*. In turning the eyes upward, except in cases of strong convergence, the rotation also decreases slightly but does not reach zero;† in strong convergence it increases as stated by Meissner.

5. Besides the rotation produced by optic convergence there is also a decided inclination of the vertical line of demarkation upon the horizontal line of demarkation, which increases with the degree of convergence. This change in the relation of these two lines is probably the result of distortion of the ocular globe.

* While these pages were passing through the press, I discovered that in this conclusion I had been anticipated by Donders and others. All previous experiments, however, were made by means of glasses. Mine were made with the naked eye.

† See this statement modified in note on p. 165.

6. As a necessary consequence of the rotation of the eyes, for all degrees of convergence in the primary visual plane, the Horopter is a *line* inclined to the visual plane, the lower end nearer the observer; but whether the inclination increases or decreases with distance I have not been able to determine with certainty. It probably increases with distance.

7. In inclining the visual plane below the primary position, the inclination of the horopteric line becomes less and less until when the visual plane is lowered 45° the horopteric line becomes perpendicular to that plane and at the same time expands into a surface. Below 45° the Horopter again becomes a line, but now inclined in the contrary direction, i. e., the *upper* end nearer the observer.

8. In inclining the visual plane upward or toward the brows, if the optic convergence be strong, the inclination of the horopteric line increases, but if the optic convergence be small it decreases but does not reach zero or become perpendicular.*

9. In looking downward 45° for all distances the Horopter is a *surface* passing through the point of sight and perpendicular to the median line of sight, but the form of the surface I have not attempted to determine. In looking straight forward at infinite distance the Horopter is also a *surface* passing through the point of sight, but the inclination of this surface I am unable to determine.

10. It is possible that in some eyes which would be considered normal there is, in convergence, a rotation of the eyes *inward*, probably from greater power in the *superior* oblique. In such cases the position of the Horopter would be different.

Columbia, S. C., Nov. 16, 1868.

ART. XII.—*Contributions to Chemistry from the Laboratory of the Lawrence Scientific School.* No. 6.—*On a new Salt containing Tin, Cæsium and Chlorine;* by S. P. SHARPLES, S.B., Assistant in the department of Chemistry.

SOME time during the month of November, 1868, Dr. Gibbs called my attention to the fact that when a solution of the chlorids of tin was added to one containing the chlorids of sodium, potassium, lithium, cæsium and rubidium, together with free chlorhydric acid, a heavy white crystalline precipitate was formed. Upon examination I found that this substance consisted almost entirely of a salt containing cæsium; this salt was so pure even from one precipitation that it gave the violet flame characteristic of the metal, and upon examination with the

* See this statement modified in note on p. 176.

spectroscope showed only faint traces of the other metals of the alkaline group.

The crude salt was dissolved in a large quantity of water to which some chlorhydric acid was added and the solution evaporated until crystals began to form on the surface of the liquid. It was then allowed to cool and the resulting crystals filtered off, washed with chlorhydric acid and dried. They were then found to be entirely free from even traces of the other alkalies. Two separate portions of the crystals were weighed out and treated with dilute nitric acid, which on boiling precipitated the tin completely as SnO_2; this was filtered off and the chlorine determined as chlorid of silver. In the first analysis ·4105 gram of the salt gave ·1004 grams of SnO_2 and ·5844 grams of AgCl. In the second, ·4767 grams gave ·1169 grams of SnO_2 and ·6727 grams of AgCl or in per cent—

	I.	II.	Calculated.
Cl	35·22	34·91	35·84
Sn	18·12	18·18	19·49
Cs by dif.	46·66	46·91	44·67

This it will be seen corresponds very nearly to the formula $SnCs_2Cl_6$, so that the salt is analogous to the well known platinum salt $PtCs_2Cl_6$. Like this it crystallizes in the regular system.

In order to ascertain whether the salt might be made use of for detecting cæsium in minerals, three or four grams of Hebron lepidolite were fused with about their own weight of carbonate of soda and treated with HCl to remove the silica. To the strongly acid liquid a solution containing stannic chlorid was added; a slight turbidity was at once produced; upon standing a few hours a white precipitate settled to the bottom. The supernatant, liquid was then poured off, the precipitate washed with HCl and examined before the spectroscope; it was found to consist almost entirely of the cæsium salt.

The new salt will not serve for a quantitative separation of cæsium as it is slightly soluble even in strong chlorhydric acid. If the stannic chlorid is added to a neutral solution containing CsCl no precipitate is formed, but upon adding to the solution about its own volume of strong chlorhydric acid the salt is at once thrown down. Alcohol does not seem to have any influence upon the precipitation.

The double salts of the other alkaline metals with tin seem to be perfectly soluble in chlorhydric acid, rubidium perhaps the least so, but even this is not insoluble enough to interfere with the complete separation of the cæsium. As a method of preparing the salts of cæsium in a state of purity the precipitation of the metal in the form of chloro-stannate appears to present great advantages.

Cambridge, Dec. 31st, 1868.

ART. XIII.—*Upon the Atomic Volumes of Liquids;* by FRANK WIGGLESWORTH CLARKE, S.B.

IF we divide the weight of a given bulk of any liquid at 0° by the weight of an equal bulk of its vapor at the same temperature, it is plain that the quotient will represent the number of volumes of vapor formed by one volume of the liquid, supposing both to exist at the above named temperature.

These quotients I term the *vapor volumes* of liquids. It is true that but few liquids can form vapor at 0°, and therefore these vapor volumes are fictitious quantities: yet, nevertheless, real or imaginary, exceedingly interesting results may be obtained by comparing them.

Of the relations existing between the vapor volumes of different liquids, I shall have but little to say in this paper, except in so far as they have been instrumental in determining atomic volumes. However, I will state as briefly as possible the leading results I have obtained by their comparison, but, as I am still at work upon the subject, I shall not enter into details.

In any homologous series of liquid compounds, the first member of the series possesses a higher vapor volume than the second, the second higher than the third, and so on indefinitely. I have yet found no exception to this rule, although I have calculated the vapor volumes of more than 400 different liquids. Furthermore, the difference between the vapor volumes of the first and second members of a series is greater than the difference between those of the second and third, and this again, greater than the difference between the third and fourth, and so on. The only exceptions I have found to this rule lie among compounds which stand so high in their respective series that the differences between their vapor volumes are very small, and consequently a very slight error in determining the specific gravities of the liquids is enough to account for the trifling variations from the rule. Even these exceptions are rare.

The first of these rules may be carried still farther. If we calculate the number of volumes of vapor actually formed at the boiling point by one volume of liquid at 0°, we shall find that the first member of a series forms more vapor than the second, the second more than the third, and so on as far as I have had data from which to calculate.

Hence it seems that the usual increase in the boiling points as we ascend in a series, is not sufficient to counterbalance the decrease in the vapor volumes. Since, however, the differences between the vapor volumes are constantly diminishing as we

ascend in any series, it seems almost certain that there must be a point at which the increase in the boiling points will overcome the decrease in the vapor volumes, and therefore the amounts of vapor formed by the members of the series at their boiling points must begin to increase with every step upward. I have as yet found no such point, however, in any series upon which I have calculated.

In any series of substitution compounds, as a rule, the vapor volumes diminish as the atomic weights increase.

Chlorid of arsenic has a lower vapor volume than the fluorid. Bromids have lower vapor volumes than the corresponding chlorids, and iodids still lower than bromids. Sulphids, also, have lower vapor volumes than the corresponding oxyds.

Last of all I give the rule upon which most of my work upon atomic volumes is based. Whenever two compounds have equal vapor volumes, their atomic volumes also are equal, or nearly so, and, as a general rule, the greater the vapor volume the less the atomic volume, and *vice versa*. There is not an actual inverse ratio between the vapor volumes of liquids and their atomic volumes although a casual glance at the numbers would seem to suggest one. It must be remembered that the vapor volumes are calculated from the specific gravities of liquids at 0°, while the atomic volumes are referred to the boiling points, and therefore an exact inverse ratio would be very improbable.

Although as yet I have found no relations between the vapor volumes of liquids which would enable me to calculate their specific gravities at 0° from their composition, still the relations which I have found seem to me to indicate decidedly the existence of definite relations between the atomic volumes of liquids, their boiling points, and their rates of expansion.

We now come to the subject named at the head of this paper,—the atomic volumes of liquids. In 1855 Kopp published several articles upon this subject.* In them he described a method of calculating the atomic volumes of liquid compounds, showing that the atomic volume of any compound equalled the sum of the atomic volumes of the elements composing it, just as its atomic weight equalled the sum of the atomic weights of its constituent parts. For a large number of compounds he actually determined the atomic volumes, and thence deduced those of the elements contained in them; but, as he employed the old atomic weights, the numbers he gave for oxygen, sulphur, and carbon, have since been doubled. With this correction the list stands as follows. Hydrogen 5·5, chlorine

* "Annalen der Chemie und Pharmacie," xcvi, 153 and 303, xcvii, 374, xcviii, 367.

22·8, bromine 27·8, iodine 37·5. Oxygen, in the radical 12·2, out of the radical 7·8. Sulphur, out of the radical 22·6, in the radical 28·6. Nitrogen, in compounds of the ammonia type 2·3, in hyponitric acid 8·6, and in cyanogen 17. Carbon 11. Besides these he also determined experimentally the atomic volumes of the following compounds, some of which are amended to suit the new atomic weights.

PCl_3 93·9, PBr_3 108·6, $AsCl_3$ 94·8, $SbCl_3$ 100·7, $SbBr_3$ 116·8, $SiCl_4$ 122·1, $SiBr_4$ 144·2, $SnCl_4$ 131·4, $TiCl_4$ 126·0.

Kopp suggested at the time, that probably phosphorus and arsenic had equal atomic volumes, and added to them silicon also, whose chlorid, regarded as $SiCl_3$, gave the number 91·6. Silicon now, however, stands apart. Tin and titanium also he regarded as having equal atomic volumes, but changing the atomic weight of silicon has brought that element near these two, so that the atomic volume of titanium agrees better with that of silicon than with that of tin.

As I shall show hereafter, tin stands by itself, having an atomic volume different from either silicon or titanium. Moreover, the fact that the atomic weights of silicon and titanium are nearer together than those of titanium and tin, goes to show that if titanium be classed with either, it should be with silicon.

As I previously stated, whenever two liquids have equal vapor volumes their atomic volumes also are equal, or nearly so. For instance, the various isomeric ethers formed by the homologues of formic acid with the methyl series of hydrocarbons, (ethyl acetate, formate, &c.,) have both equal atomic volumes and vapor volumes, and so on with all strictly isomeric bodies. Again, to cite an example of liquids diverse in their natures, benzol, butyronitrile, and bromid of ethylene, all have the vapor volume 257. Their atomic volumes, calculated by Kopp's method, are respectively 99, 99·5, and 99·6. I could cite many other examples, but it is not necessary. There are exceptions, however, though they are not common.

Suppose now we wish to determine the atomic volume of any element in its liquid compounds,—boron, for example. The terbromid of boron has the vapor volume 239. Acetic anhydrid has the vapor volume 238. Therefore the atomic volumes of these two compounds must be nearly equal. The atomic volume of the anhydrid is 109·2, calculated by Kopp's process. Regarding this as also the atomic volume of the bromid, and subtracting from it that of the three atoms of bromine, we have left as the atomic volume of boron, the number 25·8. Triethyl boron, $C_6H_{15}B$, has the vapor volume 157, equal to that of œnanthic acid. The calculated atomic vol-

ume of the acid is 174. This, then, is also the atomic volume of triethyl boron, and, subtracting from it the atomic volume of C_6H_{15}, we have left for that of boron the number 25·5, closely agreeing with the result obtained from the bromid. But we do not get such close agreements in all cases, and therefore in order to obtain accurate results, we must compare the numbers obtained from several of the liquid compounds of the element in question, and regard the average of them all as nearest correct. Before going farther in this direction, however, let us compare the vapor volumes of a number of similar compounds of boron, phosphorus, and arsenic.

The chlorids of these three elements have respectively the vapor volumes 257, 262, and 252. The bromids of boron and phosphorus have respectively 239 and 241. Triethyl boron, triethyl phosphine, and triethyl arsine have the vapor volumes 157, 154, and 159, and triethyl phosphate and triethyl arsenate have 132 and 130.

Kopp, from the chlorids, found the atomic volumes of phosphorus and arsenic to be probably equal. The comparison of these vapor volumes confirms this view, and adds boron as also possessing the same atomic volume as phosphorus and arsenic.

To make this still more certain I have calculated the atomic volumes of these elements from the vapor volumes of their compounds, in the manner already described.

For boron I have made calculations from eleven compounds, —the chlorid, bromid, triethyl boron, trimethyl, triethyl, triamyl, and monamyl borates, ethyl diamyl, amyl diethyl, and methyl diethyl borates, and tetraphenyl diborate. In these compounds I obtained respectively as the atomic volume of boron in its liquid compounds, the numbers 30·9, 25·8, 25·5, 26·0, 24·1, 26·1, 19·7, 25·3, 31·9, 24·1, and 19·9. The average is 25·4.

Although there are very great variations between these different numbers, it will be seen hereafter that the averages obtained by this method agree closely with the numbers found by actual experiment.

The atomic volume of phosphorus I have calculated in a similar manner in eleven of its liquid compounds, exclusive of the chlorid and bromid. I include Kopp's numbers for these last, however, for the sake of completeness in making up the average.

The list of compounds then stands as follows. The chlorid, bromid, oxychlorid, oxybromid and oxybromochlorid of phosphorus, triethyl phosphine, triethyl phosphite, diamyl phosphoric acid, triethyl phosphate, tetrethyl pyrophosphate, and the ethyl, butyl, and amyl chlorophosphites. In these, giving

Kopp's numbers for the first two, the atomic volume of phosphorus is found respectively as follows: 25·5, 25·2, 26·2, 25·8, 22·4, 25·5, 26·1, 23·2, 29·3, 32·3, 27·1, 27·1, and 19·7. The average of these, 25·8, agrees very closely with Kopp's numbers, and varies only 0·4 from the average obtained for boron.

The atomic volume of arsenic I have deduced from the vapor volumes of three of its compounds exclusive of the chlorid. In the chlorid the element has the atomic volume 26·4, (Kopp) and in triethyl arsine, triethyl arsenite, and triethyl arsenate, I obtain the numbers 25·5, 26·7, and 29·2. The average of all four numbers is 26·9.

If now, regarding boron, phosphorus, and arsenic, as possessing the same atomic volume in their liquid compounds, we take the average of the numbers obtained from the twenty-eight compounds in which that atomic volume has been determined, we get the number 25·8. To these three elements we can probably add vanadium, which Roscoe has shown belongs in the same group. There is but one liquid compound of this metal for which I had data to calculate from,—the oxychlorid, Roscoe's "vanadyl trichlorid," $VOCl_3$. Calculating its vapor volume, and thence the atomic volume of vanadium, I obtained the number 27.4.

It will be seen that a number of compounds of boron, phosphorus, and arsenic gave higher results than this, and therefore, for a single compound, this number seems close enough to that found for the other three elements, to be classed with them. This view is somewhat strengthened by the fact that the atomic weight of vanadium is intermediate between those of phosphorus and arsenic.

For antimony, as already stated, Kopp determined the atomic volumes of the chlorid and bromid. Deducing the atomic volume of antimony from these, we get the numbers 32·3 and 33·4. In addition to these I have determined from their vapor volumes the atomic volumes of triethyl and triamyl stibine, and the chlorid and bromid of triethyl stibine. From these I obtain respectively as the atomic volume of antimony, the numbers 33·3, 32·1, 32·9, and 35·9. Adding in these with the numbers from the chlorid and bromid of the metal, we get 33·3 as the average.

In the case of bismuth there is but one liquid compound for which I had the necessary data. Triethyl bismuthine has the vapor volume 138, while triethyl stibine has the number 141. These are so near together that it seems probable that bismuth in its liquid compounds has the same atomic volume as antimony. But more data are needed to decide this point definitely.

In the case of silicon, thanks to the labors of Friedel, Crafts, and Ladenburg, materials were more abundant. Apart from the chlorid and bromid, whose atomic volumes were determined by Kopp, I have calculated the vapor volumes of sixteen liquid compounds of silicon, and thence the atomic volume of silicon itself. These compounds are tetramethyl, tetrethyl, and tetraamyl silicates, diethyl, diethyl dimethyl, triethyl methyl, triamyl ethyl, diamyl diethyl, and trimethyl ethyl silicates, hexmethyl and hexethyl disilicates, ethylsilicic monochlorhydrin, dichlorhydrin, and trichlorhydrin and methylsilicic monochlorhydrin and dichlorhydrin. In these compounds I obtain respectively as the atomic volume of silicon, the numbers 31·0, 32·8, 33·0 30·3, 32·8, 32·2, 38·8, 35·2, 30·9, 30·3, 32·8, 36·3, 32·0, 39·0, 29·9, and 34·6. Taking also the numbers given by Kopp for the chlorid and bromid of silicon, amending them to suit the new notation and new atomic weight of silicon, and thence deducing the atomic volume desired, we get the numbers 33·0 and 30·9. Taking the average of these eighteen numbers we obtain 33·1 as the atomic volume of silicon in its liquid compounds. The atomic volume of titanium, as deduced from that of the chlorid, as determined by Kopp, is 34·8. Further investigation will probably show its atomic volume to be equal with that of silicon.

The atomic volume of the chlorid of tin, as determined by Kopp, and since doubled to suit the new notation, is 131·4. This gave for tin the number 40·2. The vapor volume of the same compound gave as the atomic volume of tin, the number 40·1. I have also calculated the vapor volume of the following nine compounds containing this metal. Stanntetrethyl, stanndimethyl diethyl, stanndiethyl, stannethyl trimethyl, the chlorid, bromid, and iodid of stanntriethyl, and the iodids of stanntrimethyl and stanndimethyl. From the vapor volumes of these liquids I have obtained respectively as the atomic volume of tin the numbers 46·5, 42·0, 39·3, 44·0, 37·7, 42·1, 41·0, 41·8, and 44·0. Including the number deduced from the chlorid of tin, we get as the average 41·8, the atomic volume of tin in its liquid compounds.

In the case of zinc there were but three liquid compounds for which I was able to calculate the vapor volumes. These were zinc ethyl, zinc methyl, and zinc amyl. The atomic volume of zinc, deduced from their vapor volumes, I obtained respectively as 23·2, 24·2, and 23·2. The average is 23·6.

Of liquids containing selenium I have the vapor volumes of but two,—the oxychlorid, $SeOCl_2$, and monohydrated selenic acid. The latter of these, however, has never been obtained

free from an excess of water, the strongest containing only about 97 per cent of monohydrate; and therefore its atomic volume, as deduced from its vapor volume, is undoubtedly a trifle too low. Be that as it may, however, in these two compounds I obtained as the atomic volume of selenium the numbers 24·7 and 21·8, the mean being 23·2. This is only 0·6 greater than the number given by Kopp as the lower atomic volume of sulphur, and, therefore, taking into account that sulphur and selenium in the solid condition have equal atomic volumes, it seems almost certain that the same equality holds true in their liquid compounds.

I determined the vapor volumes of two lead compounds, lead tetrethyl and lead triethyl, but, to my great surprise I obtained the same number for both. This is so anomalous that I am inclined to think either that there is an error in the numbers published as the specific gravities of these liquids, or else that their vapor densities do not follow the usual law. At all events I could get nothing reliable from them.

From the vapor volume of chlorochromic acid I determined its atomic volume, and thence that of chromium in liquid compounds, as 43·6. The vapor volume of the fluorid of arsenic gave me the means of ascertaining the atomic volume of fluorine, for which I obtained the number 10. But as each of these was determined from only one compound of the element, I place no great reliance upon either, regarding them merely as possible approximations to the truth.

In order to test more thoroughly this process of determining atomic volumes by means of vapor volumes, not being content with the coincidence of my numbers with those of Kopp in the cases of phosphorus, arsenic, antimony, silicon and tin, I calculated the atomic volumes of chlorine, bromine, and iodine by the same method. For chlorine, in an average of forty-one compounds, I obtained the number 22·9, Kopp's determination giving 22·8. Bromine, in an average of fourteen compounds, gave me 28·0, Kopp's number being 27·8; and iodine, calculated from nine of its liquid compounds gave the number 38·5, that of Kopp being 37·5. To this determination of the atomic volume of iodine I shall refer again hereafter.

In regard to phosphorus, arsenic, antimony, silicon, and tin, my determinations might be regarded by some as labor lost, after Kopp's examination of the chlorids and bromids. But, very frequently, the atomic volume of a single compound as calculated by Kopp's method, varies considerably from that actually found. Therefore, in order to determine accurately the atomic volume of any element in its liquid compounds it is necessary to ascertain the atomic volumes of a number of those compounds.

The examination of one, or even two or three compounds of any element may give a very different result from that which would be obtained from a larger number of determinations. For instance, Kopp's earlier experiments upon a small number of liquids gave him the number 4·7 as the atomic volume of carbon (C=6), but, upon examining a larger number of compounds he obtained the number 5·5. Doubling these to agree with the modern atomic weight of carbon, and we have a difference of 1·6. Therefore my results in the cases of the elements above named are useful as confirmatory of Kopp's. My determinations for boron, bismuth, vanadium, selenium, and zinc, however, are entirely new.

The atomic volume of mercury at its boiling point I have calculated directly from the metal itself, by the data furnished by Regnault. According to this chemist, the specific gravity of mercury at 0° is 13·5959, its boiling point is 350°, and one volume of the metal at 0° becomes at 350°, 1·065743 volumes. From these data I find the specific gravity of mercury at its boiling point to be 12·7572, and dividing the atomic weight by this number I get 15·68 as the atomic volume.

It will be seen here that I assume that mercury when free has the same atomic volume as when combined. This appears true for bromine, ammonia, cyanogen, and hyponitric acid, according to Kopp's determinations, and therefore it seems allowable to regard mercury as following the same rule. Possibly this metal may have more than one atomic volume, like oxygen, nitrogen, or sulphur; in that case 15·68 is probably either one of them or their mean. If all elements possessing but one atomic volume in their liquid compounds follow after bromine, then we can calculate approximately their specific gravities at their boiling points. That of hydrogen would be 0·1818, and that of carbon 1·0909. This, however, is a mere matter of curiosity at present.

Having now the atomic volumes of twenty elements in their liquid compounds at their boiling points, we may proceed to compare the numbers, and see if there are any definite relations between them. Of the relations found between the atomic volumes of compounds by Schröder and Kopp I shall have nothing to say, since more important relations between the elements seem to exist.

Hydrogen, having in liquids the atomic volume 5·5, is most readily substituted, atom for atom, by chlorine, bromine, iodine, and hyponitric acid. These have respectively, according to Kopp, the atomic volumes 22·8, 27·8 37·5, and 33.

The last of these is an exact multiple by a whole number of that of hydrogen, and the second varies but 0·3, the first by

0·8, and the third by 1·0 from multiples of the same. Now since Kopp does not claim rigid accuracy for his numbers, perhaps we may be justified in altering these to multiples of 5·5. Then for chlorine, bromine, and iodine we shall have the atomic volumes 22, 27·5, and 38·5. The last of these, it will be seen, is the same number which I deduced from the vapor volumes of nine compounds of iodine. The lower number was deduced from only three compounds,—the iodids of methyl, ethyl, and amyl, whose atomic volumes were determined by actual experiment. The atomic volume of iodid of methyl, according to Kopp, is from 65·4 to 68·3, that of iodid of ethyl from 85·9 to 86·4, and that of the amyl compound from 152·5 to 158·8. If now we calculate the atomic volumes of these three compounds, we shall find that if we regard iodine as having the atomic volume 37·5, we shall get a better agreement with the numbers found for the second of these compounds than if we ascribe to this element the value 38·5; but in the first and third cases, although the lower value for iodine agrees best with the lower of the two numbers between which the atomic volume of each compound varies, the value 38·5 agrees more nearly with them than between those numbers. In other words, we shall get a closer agreement with the results of experiment, if we ascribe to iodine the atomic volume 38·5, than if we give it the lower number obtained by Kopp.

The atomic volumes of seventeen organic liquids containing chlorine, have been determined by Kopp. When two values are given for one liquid I take the mean between them, and then I find upon calculating their atomic volumes, that the number 22 for chlorine agrees best with the determinations in seven cases, while Kopp's number affords a closer agreement with the numbers found for the remaining ten.

For bromine, out of five compounds whose atomic volumes have been actually determined, Kopp's number coincides best with the results found for four, while the altered number is nearer to the value obtained for the remaining one. Yet the alteration of Kopp's numbers is least in the case of bromine. Let us now examine some other groups of elements in a similar manner.

Since hyponitric acid, replacing as it does, hydrogen atom for atom, possesses an atomic volume an exact multiple of that of hydrogen, let us take this compound as our starting point for the nitrogen group. According to Kopp, nitrogen has three atomic volumes; in ammonia 2·3, in hyponitric acid 8·6, and in cyanogen, 17·0.

If now we alter the first to 2·15, and the third to 17·2, leaving the second (our starting point) as it is, then the second becomes exactly four times the first, and the third just twice the

second. In other words, the higher atomic volumes of this element become multiples by whole numbers of the lower. This coincidence seems too remarkable to be accidental. For boron, phosphorus, vanadium, and arsenic, the number 25·8 was found as the atomic volume. This is exactly three times 8·6, our starting point for this group. The number obtained for antimony, 33·3, it will be seen lacks 1·1 of a multiple of 8·6. But of the six compounds of antimony from which I calculated, two contain chlorine, and two bromine.

In my calculation I employed Kopp's values for those elements. If, however, the altered numbers are the true atomic volumes of chlorine and bromine, then we must re-calculate the atomic volume of antimony. Doing this, using the altered values for chlorine and bromine, we obtain as the atomic volume of antimony, the number 34·2. If we take the atomic volumes actually found for the chlorid and bromid of antimony, and from them determine the value of antimony, using the new numbers for chlorine and bromine, we obtain a mean of 34·5. 34·4 is just four times 8·6 ! This seems to lend additional strength to the idea that the chlorine group of elements have atomic volumes which are multiples by whole numbers of that of hydrogen.

If, however, we re-calculate the atomic volume of antimony on the basis of new values for chlorine and bromine (iodine also, whenever necessary), we must do the same for boron and the elements classed with it. Doing this, we obtain the number 26·4, a variation of only 0·6 from the multiple of 8 6 previously found.

In making these corrections it must be borne in mind that whenever the atomic volume of an element is deduced from the vapor volume of a compound, if that vapor volume is compared with that of a compound containing either chlorine, bromine, or iodine, then the atomic volume of the latter must itself be corrected, before deducing from it that of the element in question.

Passing now to the oxygen group, we have two atomic volumes given by Kopp for oxygen, 7·8 and 12·2. Between these two I have yet found no relation. But mercury, as calculated from the metal, has the atomic volume 15·68. 15·6 is just twice 7·8. Zinc, having according to my calculation the atomic volume 23·6, exceeds by only 0·2 a multiple of 7·8 by 3. For sulphur, Kopp gave the numbers 22·6 and 28·6. Between these two I have found no relation, but the lower one varies only 0·8 from three times 7·8. For selenium I obtained the number 23·2, only 0·2 less than the same multiple of 7·8. Hence it seems very probable that the true lower atomic volume for sulphur and selenium is 23·4.

I have found no relation, however, between the higher atomic volumes of oxygen and sulphur.

One more group remains, that of tetratomic elements. Of these, carbon, as determined by Kopp, has the atomic volume 11. For silicon I obtained the number 33·1, almost exactly three times 11. Altering this, as in the case of antimony, to agree with the altered atomic volumes for chlorine, bromine, and iodine, we get 33·7, still near enough to 33 to be regarded as following the usual rule.

In the case of tin we meet the first and only obstacle to this rule in the list of elements whose atomic volumes have been determined. For this metal I obtained by means of the vapor volumes of ten of its compounds, the atomic volume 41 8. Corrected for chlorine, bromine, and iodine, it stands 41·5, the nearest multiple of 11 to this being 44. Therefore either tin is an exception to the generality of cases, or else my determination of its atomic volume is incorrect.

For the chlorid of tin, the atomic volume found was 131·4. If we regard chlorine as possessing the atomic volume 22, then tin in this compound has the value 43·4. Also from the vapor volume of stanntrimethylethyl I obtained the number 44·0 as the atomic volume of tin. Therefore it is not unlikely that a more accurate investigation will decide the atomic volume of this metal in its liquid compounds to be 44, but for the present it must remain in doubt.

This comparison of the atomic volumes of these elements in their liquid compounds at their boiling points, makes it therefore extremely probable that the atomic volume of every element in the liquid condition is a multiple by a whole number of that of the element typifying its group. That is, the atomic volumes of monatomic elements are multiples of 5·5, those of diatomic elements, of 7·8, those of triads, of 8·6, and lastly those of tetrads, multiples of 11, and consequently also of 5·5. Tin may be an exception, but the only one in twenty elements. Whether this rule be absolutely true or not, however, it will be seen to be very near the truth, since in only one case, that of iodine, have I altered the number found by so high a quantity as 1·0, and that in many cases, a change of only from 0·1 to 0·3 was necessary.

Furthermore, the numbers 5·5, 7·8, and 8·6 are not numbers for which we would expect to get exact multiples, unless some definite law accounted for it. Coincidences in two or three cases might be ascribed to accident, but in nineteen cases, all probability is against such an idea. I should not venture to alter any of Kopp's numbers, had he claimed rigid accuracy for them, and the variations between his own earlier and later results for carbon, seem to render such alterations as I have made, more

justifiable. His later numbers for oxygen, hydrogen, and carbon, having been deduced by comparing the atomic volumes of forty-five compounds containing them, it will be seen I have not changed at all. His numbers for chlorine, bromine, iodine, and sulphur, however, which I have altered the most, were obtained from a comparatively small number of compounds containing them.

If my alterations be accepted, and also my new determinations, then the list of the atomic volumes of elements in their liquid compounds at their boiling points will stand as follows. Hydrogen 5·5, chlorine 22·0, bromine 27·5, iodine 38·5, oxygen 7·8 and 12·2, sulphur 23·4 and 28·6, selenium 23·4, mercury 15·6, zinc 23·4, nitrogen 2·15, 8·6, and 17·2, boron, phosphorus, vanadium, and arsenic 25·8, antimony, and possibly also bismuth 34·4, carbon 11·0, silicon, and titanium 33·0, tin, doubtful, either 41·5 or 44·0, probably the latter.

Note.—For the benefit of any who may wish to consult the authorities upon the subject of atomic volumes, I will state that, apart from Kopp's original articles, previously referred to, the best summaries I have been able to find are in the following works. "Watts' Dictionary," vol. 1, article "Atomic Volume." Kekulé's "Lehrbuch der Organischen Chemie," vol. 1, and Buff, Kopp, and Zamminer's "Lehrbuch der Physikalischen und Theoretischen Chemie."

ART. XIV.—*On the Occultator;* by Prof. LEWIS R. GIBBES, Prof. Astronomy, &c., in College of Charleston, Charleston, S. C.

IN the years 1848–1854, I was much engaged in observing occultations of fixed stars by the moon, and as a means of obtaining the approximate times of disappearance and reappearance with less labor than by calculation, I devised and constructed, in 1849 or 1850, an instrument for that purpose, to which I gave no special name. This instrument is still in my possession, but not in use, as certain parts, presently to be mentioned, have deteriorated with the lapse of time.

The Rev. Thomas Hill, of Cambridge, Mass., has published in the Nov. number of this Journal, a description and figure of an instrument for the same purpose, invented by him in 1842, and called by him the occultator. As the two instruments have the same end in view, there is a general agreement in plan, but the details differ. Mine is founded on the well known method of orthographic projection usually adopted in projecting eclipses and occultations, and I have published no description of it, nor do I propose doing so at the present time; but I wish to mention now, the devices I adopted to overcome certain difficulties which present themselves in both instruments,

and the following explanations will be sufficiently intelligible, without a figure, to those familiar with the subject.

Mr. Hill finds the desired projection, on the plane of the instrument, of any point above that plane, as the extremity of a steel rod, by means of a silk thread stretched on a brass bow, set on a triangular base, and made normal to the chart or plane of the instrument, by screws in the base. I effect the same end very simply and readily by the following expedient, based on the optical principle that an incident ray and the corresponding reflected one *coincide when they are normal to the reflecting surface.* A bit of a good glass mirror with parallel surfaces, and a few inches square, having two lines traced on it with a writing diamond perpendicular to each other, is placed on the plane of projection, and moved under the given point, representing the place of observation, until by the eye placed above that point and close to it its image is seen to coincide with the intersection of the lines on the glass. Evidently, this intersection is then the projection required on the plane of the mirror, and the corresponding point on the plane of the instrument is easily determined, if desired, by the use of the intersecting lines as lines of reference. In my instrument there is no necessity for determining this point on the plane of the instrument, as the time of disappearance is found by moving the point representing the place of observation, and the disc representing the moon, to successive corresponding positions belonging to successive minutes of time, until *the image of the point is occulted by the disc*; the time of reappearance is determined in like manner. Instead of the pointed extremity of the rod, may be used a minute perforation in a thin sheet of metal or of pasteboard, through which may be viewed its image in the mirrors. If instead of either of these, were used a polished bead of glass or metal, smaller than the pupil of the eye, the light reflected from it would be seen in the mirror as a star-like point, which by the principles of the projection employed, would be the representatives of the star to be occulted, and by the interposition of the disc representing the moon, would actually disappear, and again reappear, as in an occultation. The use of the minute perforation gives the best results, as the eye cannot then fail to be in the proper position above the point indicating the place of observation.

I use the same method for adjusting in position a plane which in my instrument represents the plane of the parallel of latitude of the place of observation; this revolves about an axis, to which ought to be parallel the plane of the instrument or the chart, and this parallelism I test by finding, by reflection, the projections of a certain point in three or more widely distant inclined positions of the plane; these projections ought to

lie in a right line. This plane ought also to form with the plane of the instrument, or plane of projection, an angle equal to the complement of the declination of the star, and any line in it, perpendicular to the axis of rotation, being taken as radius, will have its projection equal to the sine of the declination. Having a scale of equal parts, for sines, drawn on the plane of the instrument, corresponding to a certain line in the movable plane as radius, I take from a table of natural sines the proper length for the given declination, and placing the intersection of the cross lines on the mirror, to coincide with the proper point in the scale for sines, I rotate the plane about its axis, until the image of the extremity of the radius adopted coincides with the center of the cross; the plane will then have the proper angle, without requiring an arc divided into degrees and parts as in Mr. Hill's instrument.

Mr. Hill mentions several methods of adjusting the varying relation between the moon's hourly motion and semi-diameter, and decides finally upon a fixed permanent scale, in inches and parts, for hourly motion, and calculates the corresponding values of semi-diameter and parallax, in order to avoid the labor of dividing in every case the moon's hourly motion along its path into minutes of time. I adopt a permanent scale of ten inches for the earth's radius, (which fixes moon's semi-diameter also) compute the value on this scale for the hourly motion of moon in her orbit, from the horizontal parallax and hourly motions in R. A. and Dec., for each occultation, and adjust the instrument for this varying quantity, by using a scale of equal parts for minutes of time, *laid down on an extensible sheet.* This sheet is of caoutchouc, and *the scale is made variable by extending the sheet,* until sixty minutes or one hour on the scale corresponds in length with the computed value of the hourly motion of the moon. Two such scales might be used if the uniformity of the rate of extension of the sheet could not be trusted throughout the required extent of the variation of hourly motion in different parts of the orbit. These scales, made of the vulcanized caoutchouc obtainable at the date of the construction of the instrument, have now lost their elasticity and must be replaced before I can again use the instrument.

These expedients are simple, and I make them known, as the adoption of one or both may add to the efficiency of Mr. Hill's instrument, or similar instruments. I am not aware that any one had proposed them at the time I applied them to my instrument. I have heard that Mr. Adie of Edinburgh has proposed something similar to the last to thermometer scales I believe, but I do not know the date of his proposal, nor whether it has been adopted in the scales of any instruments.

College of Charleston, Charleston, S. C., 19th Dec., 1868.

ART. XV.—*On the wave lengths of the Spectral Lines of the Elements;* by WOLCOTT GIBBS, M.D., Rumford Professor in Harvard University. Read before the National Academy of Sciences, Aug. 16, 1867.

IN a memoir published in the Philosophical Transactions for 1864, Mr. Huggins has given for a particular scale the relative positions of a number of spectral lines. The scale selected was purely arbitrary. The number of elements examined was twenty-eight, and as the measurements were made with much accuracy it seemed to be desirable to extract from them all the information which they were capable of giving. For this purpose I have endeavored to determine the wave length of each line with as much precision as the present state of science permits, and in this manner to form tables which might enable me to determine whether the spectral lines are distributed according to definite laws, and if so, whether they can be considered as particular cases of the general principle of interferences.

The materials at my disposal were as follows: First, measurements by Angström of the wave lengths of 37 lines identified with particular elements and expressed in ten-millionths of a Paris inch. These were reduced to millionths of a millimeter by multiplying them by the constant 27·07. Second, measurements by Ditscheiner of 107 wave lengths, those of Fraunhofer's lines A, B, H and H′ not being available. The entire number of spectral lines measured upon his scale by Mr. Huggins is about 1000, distributed among the elements as follows:

Oxygen	32	Thallium	16	Mercury	24
Hydrogen	1	Silver	18	Cobalt	75
Nitrogen	74	Tellurium	44	Arsenic	31
Sodium	9	Tin	18	Lead	22
Potassium	15	Iron	102	Zinc	28
Lithium	3	Cadmium	15	Chromium	65
Calcium	50	Antimony	67	Osmium	18
Barium	31	Gold	23	Palladium	43
Strontium	71	Bismuth	44	Platinum	20
Manganese	46				

With respect to Ditscheiner's measurements I may here state that I have reduced them as in my memoir on the construction of a normal map of the solar spectrum.* That is, I have taken the wave length of the more refrangible line of D, as 589·43, as determined by Angström, instead of 588·8, which is the

* This Journal, II, vol. xliii, p. 1, Jan., 1867.

value found by Fraunhofer. The reduced values as thus obtained correspond very closely with those of Angström, as I have shown in the paper referred to, excepting in the part of the spectrum between C and D.

With these materials it first became necessary to identify a sufficient number of lines upon Mr. Huggins's scale with lines the wave lengths of which had been measured. This proved to be a task of extraordinary difficulty and a severe tax upon my time and patience. Mr. Huggins's scale cannot in any part be superposed upon that of Kirchhoff. The identification of a few strongly marked lines, like those which Fraunhofer selected, is of course easy, but these do not suffice as data for interpolation. By very careful and laborious comparisons of the two scales; by observing the coincidences or close approximations of lines produced by different elements; by occasional graphical constructions, and by employing the numerical results obtained in my two papers on wave lengths already published, I at last succeeded in obtaining data covering all of Mr. Huggins's scale between 589·5, or C, and 4671, which lies about half way between G and H. Of the correctness of the identification of the lines I shall be able I think to furnish satisfactory proof.

In selecting the wave lengths to be used in interpolation, I have given the preference to the measurements of Angström. But in the part of the spectrum between C and D, these were not sufficiently numerous to be of service. For this portion I have employed exclusively the values given by Ditscheiner, reduced in the manner already pointed out. In other parts of the scale it has also been necessary occasionally to use Ditscheiner's measurements, but in all these portions the difference between the results of Angström and of Ditscheiner rarely amounts to a unit in the first decimal place.

The number of lines upon Mr. Huggins's scale identified with lines the wave lengths of which have been measured, amounts to forty-five. For the purpose of interpolation these were divided into nine groups. In table I, I have brought together for convenience both the data employed and the results obtained.

In this table the column H gives the scale-number of the line; λ the wave length as observed, λ' the wave length as calculated by the formula obtained, Δ the difference between the observed and calculated wave-lengths, and ε the probable error for each group of data. The wave-lengths marked † are those of Ditscheiner; the others are given by Angström.

TABLE I.

H	λ	λ′	Δ	ε	H	λ	λ′	Δ	ε
589·5 †	656·65	656·56	+0·09		1600	527·32	527·34	−0·02	
612 †	652·07	652·25	−0·18		1645	523·69	523·71	−0·02	
623 †	650·03	650·14	−0·11		1708	518·79	518·79	0·00	
709 †	634·23	634·03	+0·20		1723	517·66	517·65	+0·01	
772 †	623·59	623·39	+0·20		2036 †	496·11	496·05	+0·06	
795 †	619·60	619·90	−0·30		2092	492·23	492·31	−0·08	
813 †	617·48	617·39	+0·09		2147	489·50	489·45	+0·05	
818 †	616·71	616·71	0·00	± 0·18	2200	486·52	486·52	0·00	±0·04
813 †	617·48	617·42	+0·06		2147	489·50	489·51	−0·01	
818 †	616·71	616·76	−0·05		2172 †	488·18	488·11	+0·07	
843 †	612·75	612·81	−0·06		2200	486·52	486·59	−0·07	
856 †	610·80	610·73	+0·07		2236 †	484·63	484·64	−0·01	
939 †	598·12	598·13	−0·01		2315 †	480·56	480·55	+0·01	±0·04
1000 †	590·07	590·06	+0·01						
1005 †	589·43	589·45	−0·02	± 0·04	2236 †	484·63	484·91	−0·28	
					2315 †	480·56	480·26	+0·30	
1000	590·04	590·04	0·00		2785	457·75	457·74	+0·01	
1005	589·43	589·45	−0·02		3272	440·81	440·83	+0·02	
1236	561·99	562·00	−0·01		3341	438·63	438·67	−0·04	
1247	560·70	560·65	+0·05		3597	431·03	431·04	−0·01	±0·18
1251	560·26	560·22	+0·04						
1274	557·65	557·53	+0·12		3272	440·81	440·84	−0·03	
1413 †	543·37	543·30	+0·07	± 0 06	3341	438·63	438·69	−0·06	
					3532	432·78	432·81	−0·03	
1413 †	543·37	543 44	−0·07		3597	431·03	431·00	+0·03	
1422	542·83	542·91	−0·08		3728	427·45	427·46	−0·01	
1445 †	540·95	541·09	−0·14		3773	426 26	426·28	−0·02	±0·04
1481 †	537·55	537·42	+0·13						
1532	533·16	533·18	−0·02		3597	431·03	430·97	+0·06	
1545	532·00	532·01	−0·01		3728	427·45	427·45	0·00	
1582	528·73	528·69	+0·04		3773	426·26	426·29	−0·03	
1600	527·32	527·25	+0·07	± 0·07	3812	425·21	425·29	−0·08	
					3909	422·94	422·88	+0·06	
					4267	414·71	414·66	+0·05	
					4633	407·45	407·39	+0·06	
					4671	406·59	406·61	−0·12	±0·06

The method of interpolation employed was that first given by Cauchy* and afterward reduced to a practical form by M. Yvon Villarceau, in the Connaissance des Temps for 1852. As in my recent reduction† of Kirchhoff's scale, I employed only expressions of the form

$$\lambda = a + bh + ch^2 + dh^3 \text{ \&c.}$$

these being found to give an approximation within the limits of the probable errors of observation.

Table II, gives the values of the constants, *a*, *b*, *c*, and *d*, as deduced from the data given in Table I.

In this table H is the initial and H′ the terminal point of Mr. Huggins's scale in each group of data employed for discussion. For easy use in calculation it is more convenient to transfer the initial and terminal points, so as to make each parabolic curve

* Moigno. Leçons de Calcul Differentiel et de Calcul Integral. Tome Ier, 513.
† This Journal, II, May, 1868, vol. xlv, p. 1.

begin and end with a multiple of ten upon the scale. This has been done in Table III.*

TABLE II.

H	H′	*a*	*b*	*c*	*d*
589·5	818	656·5589	−19·0571	−0·4300	+0·4984
800	1018	619·5488	−15·6660	−0·3960	+0·4264
1000	1413	589·9750	−12·5440	+0 2369	+0·0165
1413	1600	543·5600	− 7·8810	−0·8653	+0·2469
1600	2200	527·3240	− 8·1670	+0·2276	------
2147	2315	489·5078	− 5·6093	+0·1622	------
2230	3597	485·2950	− 6·1092	+0·2398	−0·0061
3272	3773	440·8098	− 3·3028	+0·1019	−0·0043
3597	4671	430·9556	− 2·7232	+0·0433	------

TABLE III.

H	H′	*a*	*b*	*c*	*d*
590	800	656·4637	−19·0614	−0 4225	+0·4984
800	1000	619·5488	−15·6660	−0·3960	+0·4264
1000	1410	589·9750	−12·5440	+0·2369	+0·0165
1410	1600	543·7956	− 7·8284	−0·8875	+0·2469
1600	2200	527·3240	− 8·1670	+0·2276	------
2200	2310	486·5804	− 5·4374	+0·1622	------
2310	3270	480·5580	− 5·7372	+0·2252	−0·0061
3270	3770	440·8759	− 3·3069	+0·1022	+0·0043
3770	4670	426·3739	− 2·5734	+0·0433	------

From these tables it will be seen that in three out of the nine groups parabolas of the second order are sufficient.

If the results obtained in the discussion of Mr. Huggins's scale be compared with those given in my paper on the measurement of wave-lengths by the method of comparison in which Kirchhoff's scale is subjected to a similar treatment, the greater regularity of the former will be at once remarked. Thus in Kirchhoff's scale in two instances, parabolas of the 5th order are required. In two cases a straight line represents the observations best, the probable error being however unusually large. In the case of Mr. Huggins's scale, on the other hand, the probable error for each group appears to be much within the limits of the errors of observation. In the 6th and 7th groups of data discussed in the present paper, the intervals between the scale numbers are larger than I could have wished. Yet the differences between calculation and observation are not large, the curves here approaching a straight line. The greater regularity or relatively lower order of the curves in the case of Mr. Huggins's scale arises doubtless from the fact that the prisms employed were, during the whole series of observations, in a constant position, which was not the case with Kirchhoff's apparatus.

* In using the constants in Table III for computing wave-lengths the value of h is to be found by subtracting the initial number in column 1 from the scale number and dividing the remainder by 100.

By means of Table III the wave lengths of all the lines upon Mr. Huggins's scale between C and scale-number 4671 have been computed. These are given in Table IV. I have however not followed the order adopted by Mr. Huggins, but have put near each other as far as possible those elements which form members of natural groups.

TABLE IV.*

Nitrogen.			H		λ	H		λ	H		λ
H		λ	2205	5	486·18	2181	5	487·56	1169	2	569·46 s
629·5	2	649·08	2221	3	485·30	2213	3	485·74	1174	1	568·90 s
807	2	618·45h.d	2305	2	480·84	2502	7	470·33 n	1746	1	515·90 n
959	1	595·33	2336	1	479·08	2512	7	469·84 n	1753	5	515·37 n
967	6	594·26	2350	7	478·29	2563	5	467·38 n	1991		498·87 h
975	4	593·20	2642	2	463·78 d	2597	5	465·82 n			
978	1	592·80	2669	3	462·60	2626	2	464·50	Thallium.		
1100	5	577·53	2689	1	461·74	2642	2	463·78 d	H		λ
1118	1	575·37	2707	1	460·97	2748	1	459·27	596	4	655·32 s
1135	2	573·37	2722	1-5	460·35	2766	1	458·54	768	1	624·01 h
1150	2	571·64	2738	1-5	459·68	3086		446·75 h	921	2	600 76 s
1171	1	569·24	2856		454·96 h	3238	1	445·03 n	960	6	595·20 s
1177	8	568·55	2904	}	453·15 h	3241	1	441·75 n	1055	2	583·02 s
1180	1	568·21	2978	}	450·46 h	3395	1	436·85 n	1099	5	577·65 n
1187	7	567·43	3009	1	449·37	3456	2	435·00 n	1356	1	549·07 s
1294	5	555·56	3011	1	449·31	3560	1	431·95 n.d	1505	2	535·54 s
1302	5	554·71	3056		447·76 h	3710		427·87 h	1747	4	515·82 n
1310	1-5	553·85	3144		444·83 d	4059	1	419·29	1851	4	508·27 n
1314	5 5	553·37	3174	}	443·86 h	4087	1	418·65	1885	1	505·91 s
1319	2	552·91	3219	}	442·43 h	4232		415·43	1999	2	498·36 h
1349	1-2	549·78	3292		440·11 h	4395	2	412·01	2146	2	495·44 s
1366	1	548·04	3456	2	434·99 n	4615	1	407·82 n	2379	2	476·70 n
1383	5	546·33	3863		423·99 h	4639	1	407·31 n	2437	4	473·61 n
1394	7	545·43	3991		420·90 h				4443	2	411·16 n
1502	2	535·81	4145		417·34 h	Potassium.					
1516	2	534·57	4263		414·75 n	H		λ	Lithium.		
1537	2	532·69	4330		413·34 h	727	5	630·85 s	H		λ
1713		518·39 h	4473		410·45 n	763	5	624·81 s	856	3	610·73 s
1718		518·01 h	4505	1	409·82 n	840	1-5	613·25 s	2013	2	497·48 s
1721		517·78 h				1049	1	583·78 n	2732	5	459·93 n
1860	5	507·64	Hydrogen.			1069	5	581·79 n			
1900	3	504·88	H		λ	1073	1 5	580·80 n	Silver.		
1929	7	502·93	589·5		656·76 h	1328	1	551·96 n	H		λ
1941	5	502·12				2260	2	483·18 n	690	2	637·48 s
1951	5	501·46	Oxygen.			3328	2	438·96 n	762	2	624·96 s
1956	5	501·14	H		λ	3591	1-5	431·16 n	899	5	604·96 s
1960·5	10	500·84	807	2	618·45h.d	3762	2	426·00 n	943	5	597·58 s
1967	10	500·42	1678	5	521·10	4082	3	418·77 n	1031·2	2	586·03 s
1978	5	499·71	1699	5	519·47				1207	5	565·19 n
1990	3	498·94	1737	3	516·57	Sodium.			1223	2	563·42 n
2079	5	493·43	2043	5	495·61	H		λ	1227	7	563 00 n
2140	5	489·86	2060	7	494·58	818	1-5	616·72 s	1240	3	561·46 s
2168	5	488·28	2089	5	492·83	821	1	616·56 s	1257	7	559·57 s
2192	3	486·96	2119	3	491·07	1000	8	590·04 s	1276·3	5	557·46 s
			2145	5	489·58	1005	8	589·43 s			

* In this table the small numerals after the scale numbers give the estimated intensities of the spectral lines upon an ascending scale. The letters s, n, h and d have the following significations; s, a sharply defined line, narrow when the slit is narrow; n, a line with indistinct edges even when the slit is narrow; h, a hazy line not resolvable into finer lines; d, double but too close for measurement.

TABLE IV (continued).

H		λ	
1286·53		556·36	s
1372	2	547·44	s
1380	7	546·63	s
1421	3	542·81	s
1435	3	541·64	s
1446		540·72	h
1675	5	521·34	n

GOLD.

H		λ	
643	5	646·32	s
659	5	643·28	s
727	5	630·85	s
734	5	629·63	s
747	3	627 43	s
951	5	596·45	s
956	5	595·75	s
981	7	592·41	s
1011	1	588·62	n
1025	2	586·82	s
1045	4	584·38	s
1081·55		579·76	s
1109	1	576·44	s
1199	5	566·07	s
1266	5	558·59	n
1647	5	523 55	s
1869	5	506·87	s
2291	5	481·51	s
2326	4	479·64	s
3026	2-5	448·78	s

ARSENIC.

H		λ	
672	1	640·83	n
707	1	634·37	n
759	1	625·45	n
812	6	617·67	n
833	1	614·35	n
850	3	611·67	n
870	2	608·53	n
908·63		602·59	n
1042	1	584·66	n
1090	5	578·73	n
1203	7	565·63	n
1231	5	562·54	n
1257	5	559·58	n
1291	6	558·88	n
1348	6	549·88	n
1443	1	540·97	n
1465	1	539·08	n
1529	6	533·41	n
1577	1	529·20	n
1648	4	523·47	n
1737	1	517·63	n
1814	4	510·89	n
1993	2	498·75	n
2153	1	489·12	n
2450	1	472·95	n

H		λ	
2859	1	454·84	h
2897	1	453·40	h
3006	1-5	449·48	h
3097	2-5	446·38	h
3381	1	437·34	n
3497	1	433·77	n

ANTIMONY.

H		λ	
614	1	651·92	n
620	1	650·72	n
640	1	646·89	n
679	2	639·51	h
719	1	632·24	n
729	2	630·49	n
739	2	628·77	n
765	3	624·49	n
787	1	621·09	h
796	5	619·77	h
819	2	616·56	n
837	7	613·70	n
871	7	607·45	n
889	3	605·59	n
921·18		600·75	n
937·52		598·72	n
981·51		592·35	n
988·53		591·45	n
1000·53		589·96	n
1041	5	584·78	s
1057	5	582·77	s
1081	1	579·82	n
1145	5	572·22	n
1158	1	570·72	n
1189	5	567·26	n
1207	1	565·19	h
1214	4	564·41	n
1220	1	563·75	n
1279	4	557·18	n
1383	3	546·33	n
1457		539·77	h
1471	3	538·55	n
1501		535·90	
1636	3	524·42	h
1661	1	522·44	s
1715	3	518·24	h
1765	3	514·47	h
1803	3	511·64	h
1849	1	508·41	s
1900	2	504·88	h
1919	2	503 60	h
2051	3	495·13	n
2171	3	488·11	n
2251	2	483·67	n
2339	2	478·90	h
2377	2	476·81	h
2397	2	475·74	n
2440	2	473·46	n
2488	3	471·03	n

H		λ	
2529	3	469·01	n
2687	1	461·83	h
2740	1	459·60	h
2763	2	458·66	n
2977	2	450·51	n
3115	1	445·79	n
3359	1	437·97	h
3446	4	435·29	n
3756	3	426·68	n
3819	1	425·08	n
4043	1-5	419·67	n

BISMUTH.

H		λ	
621	4	650·53	s
837·35		613·72	n
884	5	606·36	n
887	5	605·95	s
899	1	604·06	s
939	1	598·14	h
943	1	597·58	h
1026	2	586·68	n
1059	1	582·53	n
1143	6	572·36	n
1197	3	566·31	n
1293	1	555·67	s
1305	5	554·39	s
1395	1	545·13	h
1453	1	540·12	h
1495	1	536·43	h
1598	7	527·48	n
1675	10	522·12	n
1685	1	520·56	n
1759	7	514·92	n
1787	6	513·88	n
1834	1	509·46	n
1851·35		508·41	n
1979	1	499·52	h
2015		497·36	h
2105	5	491·89	n
2119	1	491·07	n
2317	1	480·15	n
2408	1	475·14	n
2467	5	472·09	n
2502	1	470·33	n
2837	5	455·68	n
3060	1	447·62	n
3315		439·39	n
3481	3	434·24	n
3519	2	433·13	n
3619	5	430·31	n
3778	5	426·11	n
4378	4	412·85	n
4603	3	407·97	n

CALCIUM.

H		λ	
622	5	650·34	s
625	1-5	649·77	s
637		647·47	s
642	2	646·51	s
649		645·17	s
655		644·03	s
699	2	635·83	s
709	2	634·03	s
723	2	631·55	s
813	1	617·51	s
818	4	616·67	s
843	3	612·78	s
859	2	611·06	s
863	2	609·63	s
882		606·67	h
921·22		600·63	s
934		598·87	h
1031	3-5	586·05	s
1247	5	560·63	s
1249	5	560·39	s
1252	1-5	560·13	s
1256	2-5	559·69	s
1258·55		559·41	s
1260	4	559·25	s
1265	7	558·59	s
1335	7	551·23	s
1506	1	535·45	s
1599·54		527·36	s
1605	3	526·93	s
1609	5	526·61	s
1612	1-5	526·36	s
1702	1	519·24	s
1907	7	504·40	s
1935	3	502·52	s
2172	7	493·85	s
2777	5	458·10	s
2784	3	457·82	n
2792	2	457·50	s
3124	3	445·49	s
3181	3	443·64	s
3212	2	442·66	s
3561	3	431·94	s
3602·52-5		439·79	s
3617	4	430·36	s
3628	2-5	430·08	s
3665	3	429·06	s
3692	2-5	428·36	s
3909	6	422·86	s

BARIUM.

H		λ	
608	1	653·02	s
621·57		650·44	s
645	1	645·94	s
704	1	634·83	s
847	2	612·15	s
879	2	607·13	s

TABLE IV (continued).

H		λ	
908	1-5	602·70	s
925	1-5	600·18	s
943	1-5	597·58	s
993	5	590·89	s
1005	1	589·43	n
1034	6	585·67	s
1057	1	582·77	s
1096	1	578·00	s
1119	1	575·26	s
1308	4	554·06	s
1327	1	552·06	s
1351	5	549·58	s
2075	9	493·67	n
2133	4	490·23	n
2459	5	472·49	s
2535	5	468·71	s
2856	9	454·96	s
2931	3	452 23	n
4127	2	417·74	n
4332	5	413·30	n

STRONTIUM.

H		λ	
595	2	655·51	s
619	2	650·91	s
655		644·03	h
669	4	641·39	s
681	1	639·15	s
684	1	638·59	s
692	5	637·12	s
703	2	635·21	s
705	5 5	634·66	s
723		631·55	h
745	2	627·77	s
760		625·29	h
777		622·61	h
807	5	618·45	s
856	1	610·73	s
924		600·32	h
941	1	597·86	h
945	3	597·30	s
1061	5	582·29	s
1102	5	577·29	n
1203	1	565·64	n
1227	1 5	562·98	st
1268	2	558·37	s
1301	2	554·81	s
1305	2-5	554·39	s
1311	3	553·74	s
1324	3	552·38	s
1341	3	550·61	s
1349	7	549·78	h
1359	3	548·75	s
1365	4	548·15	s
1397	2-5	544·93	s
1425	2	542·48	s
1467	1-5	538·91	h
1617	3	525·95	s
1638	2	524·26	s
1651	1-5	523·23	s
1656	1-5	522·83	s
1659	1-5	522·60	s
1665	1	522·14	s
1745	1	515·98	s
1817	5	510·68	
2021	1	496·98	s
2029	2	496·48	s
2060		494·58	h
2145	1	489·57	s
2176	1-5	487·84	s
2180	1-5	487·62	s
2185	1	487·35	s
2213	1	485·74	s
2254	1-5	483 51	s
2291	1-7	481·51	s
2343	1-5	478·69	s
2410	5	475·04	s
2427	1	474·14	s
2469	1	471·98	s
2726	5	460·18	n
3169	1	444·02	s
3389	5	437·03	n
3409	5	436·41	n
3489	1	434·01	n
3553	1	432·16	h
3604	5	430·73	n
3952	5	421·83	n
4181	3	416·58	n
4599	3	408·05	n

IRON.

H		λ	
623	1	650·15	s
641·5	5	646·61	s
667	5	641·77	s
673	1	640·64	s
674	5	640·45	n
683	5	638·88	s
696·2	5	636·35	s
709	7	634 02	s
719	5	632·24	s
726	5	631·02	s
758	5	625·62	s
763	5	624·81	s
772	1	623·38	s
795	1	619·92	s
829	2	614·98	s
852	5	611·36	s
869·5	5	608·60	s
909	5	602·55	s
937	5	598·43	s
953	5	596·17	s
995	2	590·64	s
1011	2	588·62	s
1030	2	586·18	s
1090	5	578·73	s
1225	5	563·20	s
1236	1-5	561·93	s
1247	5	560·69	s
1251	2	560·24	s
1261	2	559·14	s
1274	7	557·71	s
1276	2	557·49	s
1338	7	550 91	s.d
1383	5	546·33	s
1391	7	545·53	s
1400	7	544·64	s
1413	5	543·37	s
1419	7	542·97	s
1421·5	7	542·78	s
1434	5	541·73	s
1438	5	541·39	s
1445	7	540·80	s
1446	7	540·71	s
1456	7	539·86	s
1459·5	2	539·55	s
1467	7	539·00	s
1481	1	537·67	s.d
1485·3	5	537·28	s
1486	2	537·24	s
1486·5	2	537·18	s
1488	2	537·05	s
1532	2	533·14	s
1537	7	532·69	s
1541	5	532·34	s
1545	5	531·98	s
1560	2	530 67	s
1574	2	529·45	s
1582	7	528 77	s.d
1593	5	527 84	s
1599	7	527·40	s
1600	7	527·33	s
1603	5	527·09	s
1608	5	526·68	s
1613	3	526·28	s
1621	3	525·63	s
1632	3	524·74	s
1645	1	523·70	s
1653	1	523·09	s
1662	5	522·36	s.d
1691	3	520·09	s
1696	3	519·70	s
1698	5	519·55	s
1713	7	518·39	s
1728	1	517·25	s
1731	5	517·03	s
1753	3	515·38	s
1767	7	514·33	s
1775	5	513·74	s
1821		510·40	h
1940·5	1	509·01	s
2036	1-5	496·05	s
2092	1	492·65	s
2098	7	492·30	s.d
2147	1	489·47	s
2781	5	458·02	s
3272	1-5	440·81	s
3341	2	438·55	s
3532	1-5	432·75	s
3597	1-5	430·93	s
3610	1-5	430·55	s
3623	5	430·21	s
3645	5	429·61	s
3728	2	427·40	s
3773	1-5	426·24	s
3812	1-5	425·26	s
4009	1	420·46	s
4019	1	420 23	s
4221	1	415·70	s
4267	1	414·67	s
4323	1	413·49	s
4633	1	407·41	s
4671	1	406·73	s

MANGANESE.

H		λ	
704	2	634·93	s
837		613·72	h
843		612·78	h
909	3-5	602·55	s
913	2-5	601·96	s
915·5	2	601·66	s
1289	1	556·00	s
1329	1-5	551·85	n
1376	1	547·04	s
1413	7	543·37	s
1428	1	542·22	s
1438	7	541·39	s
1443	7	540·97	s
1452	2	540·20	s
1456	2	539·86	s
1473·5	3	538·34	s
1505·5	5	535·50	s
1515	4	534·65	s
1559		530 58	h
1571		529·79	h
1617	5	525·96	s
2267		482 80	s
2343	5	478 69	s
2379	6	476 70	s
2385	5	476·38	s
2401	5	475·62	s
2433	1	473 82	s
2456	1	472 65	s
2492	7	470·83	h
2987	7	450·14	s
2999	1	450·07	s
3021	1	448·96	s
3054	1	447·83	s
3097	1	446·38	s
3102	2	446·22	s
3114	1	445·82	s

TABLE IV (continued).

H		λ	
3120	1	445·62	s
3131·53		445·31	s
3133	2	445 19	s
3141	1	444 99	s
3180	1	443·67	s
3242	1	441·72	s
3691	1	428·44	s
3749	1	426·85	s
3782	1	426·11	s
3870	3	423·84	s

COBALT.

H		λ	
645	1	645·94	n.d
701	5	635·47	s
731	2	630·75	s
745	5	627·77	s
763	2	624·81	s
844		612·62	h
865	7	609·32	s
891	7	605·29	s
921	1	600·76	s
923	2	600·47	s
931	5	599·30	s
937	5	598·45	s
985	2	591·90	s
1039	2	585·04	s
1043	2	584·53	s
1207	5	565·19	s
1217	5	564·08	s
1257	7	559·58	s
1361	1	548·55	s
1401	1-5	544·54	
1470	5	538·64	s
1483	1	537·50	s
1491	1	536·79	s
1496	2	536·34	s
1500	52	535·75	s
1501·52		535·66	s
1508	2	535·27	s
1514	4	534·74	s
1525	5	533 77	n.d
1534	5	532·96	s
1539	3	532 52	s
1543	2	532·17	s
1549	5	531·64	s
1573	2	529·54	s
1579	2	529·02	s
1584	2	528·60	s
1586	1-5	528·43	s
1591	5	528·01	s
1602	3	527·17	s
1604	3	527 01	s
1617	5	525·96	s
1619	3	525·79	s
1622	5	525 55	s
1626	3	525·23	s
1642	5	523·94	s
1650	5	523·31	s
1670	1-5	521·73	s
1685	5	520·56	s
1699	5	519·46	s
1707	5	518·85	s
1743	5	516·13	s
1756	5	515·15	s
1781		513·30	n
1813		510·96	h
1857	5	507·85	h
1876	5	506·52	s
1887	3	505·77	s
1925	5	503·19	s
2021	5	496·98	s
2186	3	487·29	s
2236	3	484·47	s
2286	2	481·78	s
2325	1	479·63	s
2409	5	475·09	s
2438	5	473·56	s
2471	5	471·98	s
2550	5	468·01	s
2785	2	457·78	n
2823	1	456 22	n
2862	3	454·73	s
2910	3	452·92	s
4388	3	412·15	n
4394	3	412·07	n
4437	1	411·16	n
4523	1	409·48	n

CHROMIUM.

H		λ	
621	5	650·53	n
640	5	646·89	n
654	1	644 22	n
817	1	616·86	n
843	1-5	612·77	n
856	7	610·73	n
1081	1	579 82	h
1087	1	579·10	h
1090	1	578·73	h
1212	1	564·63	s
1242	1	561·23	s
1439	1-5	542·14	s
1507·57		535·31	s
1510	1	535·10	s
1532	1	533·14	s
1567	1	530·07	d
1594	7	527·75	s
1605·51		526·93	s
1607	1	526·77	s
1619	5	525·79	s
1626	5	525·23	s
1640	5	524·10	s
1657	7	522·76	s
1677	4	521·18	s
1680	3	520·95	s
1681·53		520·87	s
1749	2	515·68	n
1815	7	510·82	n
2097	1	492·35	s
2156	1	488·95	s
2175	7	487·89	s
2181	3	487·57	s
2198	5	486·63	s
2257	5	483·35	s
2266	1-5	482·86	s
2336	7	479·07	s
2400	1	475·57	s
2406	5	475 25	s
2435	7	473·73	s
2452	7	472·85	s
2474	1	471·72	s
2619	1	464·81	s
2627	7	464·46	s
2632	1-5	464·21	s.d
2663	5	462·86	s
2701	7	461·31	s
2740	7	459·60	s
2768	7	458·45	s
2840	7	455·56	s
2871	7	454·38	s
2887	7	453·78	s
2899	7	453·33	s
2914	1	452·78	s
2927	1	452·30	s
3007	1	449·45	s
3444	2	435·35	s
3465	1	434·72	s
3473	1	434·48	s
3489	1	434·01	s
3663	3	429·13	s
3719	3	427·64	s
3797	3	425·64	s
3905	1	422·96	s
3951	1	421·90	n

CADMIUM.

H		λ	
639	2	647 08	n
656	8	643·84	s
889·55		605·22	n
918	1	601·22	n
953	1	596·17	n
986	1	591·77	n
1473	10	538·38	n
1517	10	534·47	n
1556	1	531 01	n
1747	1	515·83	s
1843	10	508·83	s
2315	8	480·27	s
2562	6	467·43	s
3239	4	441·81	s

ZINC.

H		λ	
696	7	637·37	s
782	1	621·84	s
855	5	610·89	n
895	1	604·69	s
909	5	602·55	n
1001	2	589·90	s
1062	5	582·16	s
1110	5	576 33	s
1122	6	574·90	n
1269	5	558·26	n
1283	1	557·75	n
1519	5	534·30	n
1626	1	525·23	n
1645	5	523·70	n
1743	5	516·13	n
1790	5	512·64	n
1797	5	512·13	n
1845	5	508·69	n
1859	1	507·71	n
1893	5	505·35	n
2016	5	497·29	n
2091	8	492·71	n
2110	8	491·60	n
2191	5	487 02	n
2294	7	481·35	s
2469	6	471 98	s
2559	4	467·58	s

LEAD.

H		λ	
898	1	604·22	s
924	2	600·33	n
1000	1	590·02	n
1015	2	588·14	n
1031·14		586·05	s
1055	5	583·03	n
1094	1	578·25	n
1240	9	561·46	
1279	5	557 18	n
1479	7	537·85	n
1593·35		527·84	n
1685	1	520·57	s
1698	1	519·54	n
1735	5	516·72	n
1900·32		504·86	n
2384	3	476·44	n
3329	7	438 93	n
3730	2	427·35	n
3831	6	424·83	n

Table IV (continued).

Mercury.				Tellurium.				Palladium.				Tin.				Osmium.			
H		λ		H		λ		H		λ		H		λ		H		λ	
685	1	638·41	n	657·37		643·59	s	685	5	638·40	s	648	7	645·27	s	641	1	646·70	s
697	1	636·20	n	693	1	636·93	s	762	2	624·96	s	1076	10	580·43	n	741	7	628·43	s
826	7	615·46	n	703	5	635·11	n	837	2	613·72	s	1219	2	563·86	s	929	7	599·59	s
863	2	609·63	n	735	2	629·46	s	995	}	590·64	} h	1260	8	559·25	n	1029	1	581·31	s
1008	1-5	589·01	n	765·33		624·44	n	1005	}	589·43	}	1284	8	557·63	n	1093	5	578·37	s
1019	5	587·59	n	774	3	623·07	s	1023	3	587·07	s	1484	1	537·40	s	1141	1	572·69	s
1060	3	582·41	n	894	2	604·84	s	1031·5		586·00	h	1506	2	535·45	n	1264	1	558.91	s
1074		580·68	h	917	1	601·37	s	1056·7		582·90	s	1520	1	534·21	h	1322	2	552·60	s
1083·58		579·51	n	927	5	599·90	n	1068		581·42	h	1524	4	533·85	n	1405	5	544·14	s
1100·58		576·93	n	945·36		597·26	s	1084		579·46	h	1576	1	529·29	n	1432	1-5	541·89	s
1177	2	568·55	n	971·51		593·66	s	1127	3	574·31	s	1657	2	522·75	n	1683	5	520·72	s
1252	1	560·13	n	1030·35		586·14	s	1129	1	574·08	s	1821	3	510·40	n	1859	5	507·71	s
1385	10	546·13	n	1035	2	585·54	s	1185	5	567·65	s	2205	3	486·17	n	2861	7	454·76	s
1421	1-5	542·81	n	1111	7	576·21	n	1199	5	566·08	s	2777	2	458·10	n	3225	2	442·24	s
1487	5	537·15	n	1122	1	574·90	s	1212	5	564·63	s	2931	4	452·23	n	3421	1	436·05	s
1583	5	528 69	n	1151	7	571·53	n	1219	}	563·86	} h					3583	1	431·33	s
1662	3	522·37	h	1204	6	565·53	n	1233	}	562·29	}					3645	1	429·61	s
1777	5	513·60	h	1230	1	562·65	s									3773	3	426·24	s
2033	1	496·24	h	1240·55		561·40	s												
2101	5	492·12	h	1248	5	560·57	s									Platinum.			
2263	5	483·02	n	1259·27		558·24	s.d									H		λ	
3421	8	436·05	n	1281	1-5	556·96	s									689	5	637·63	s
				1299	1	555·03	s									913		601·95	h
				1303	1-5	554·60	n									939		598·14	h
				1331	1-5	551·65	n									950	5	596·59	s
				1380	1-5	546·63	s									958	5	595·47	s
				1412	5	543·51	s									1041	5	584·78	s
				1456	2	539·86	s									1045	5	584·28	s
				1492	5	536·71	s									1073	7	580·80	d
				1511	5	535·01	s									1367	7	547·95	s
				1548	5	531·73	s									1459	5	539·59	s
				1569	3	529·88	s									1484	5	537·41	s
				1617	5	525·96	s									1561	2	530·76	s
				1622	5	525·55	s									1653	1	523·08	s
				1642	1-5	523·94	s									1689	3	520·25	s
				1674	7	521·42	s									1879	1	506·32	s
				1735	2	516·72	s									2857	1	454·92	s
				1798	1-3	512·05	s									2936	3	451·97	s
				1807	1	511·40	s									2999	7	449·72	s
				1873	5	506·73	s									3156	1	444·45	s
				2175	1-5	487·89	s									3525	1	432·95	s
				2279·52		482·12	s												
				3065	7	447·45	s												
				3963	4	421·57	s												

I have stated above that the principal difficulty with which I have had to contend was the identification of a sufficient number of scale lines with lines of which the wave lengths had been measured either by Angström or by Ditscheiner. Upon the correctness of this identification the value of my work depends. For the purpose of verification, before proceeding to determine parabolic formulas for different parts of the scale, I carefully compared Kirchhoff's and Huggins's scales with each other for their whole lengths, selecting the lines about whose correspondance there could be no doubt. When the formulas

had been obtained, I calculated the wave lengths for all these lines upon both scales. The results of this comparison are given in Table V.

TABLE. V.

K	H	Kλ	Hλ	Δ	E
717·5	619	650·68	650·91	−0·23	Sr
718·7	621·5	650·24	650·44	−0·20	Ba
720·1	625	649·88	649·77	+0·11	Ca
729	637	647·60	647·47	+0·13	Ca
731.7	642	646·93	646·51	+0·42	Ca
736·9	649	645·60	645·17	+0·43	Ca
740·9	658	644·60	644·03	+0·57	Ca
753·8	669	641·38	641·39	−0·01	Sr
756·9	673	640·60	640·64	−0·04	Fe
771·8	696	636·99	637·37	−0.38	Zn
831	772	623·52	623·38	+0·14	Fe
849·7	795	619·60	619·92	−0·32	Fe
860·2	813	617·47	617·52	−0·05	Ca
863·9	818	616·71	616·71	0·00	Ca
880·9	837	613 50	613·73	−0·23	Sb
884·9	843	612·94	612·78	+0·16	Ca
890	847	611·75	612·15	−0·40	Ba
894·9	856	610·80	610·73	+0 07	Ca
958·8	939	598·22	598·14	−0·08	Pt
961·5	943	597·05	597·58	−0·53	Ba
1002·8	1000	590·07	590·02	+0·05	Na
1006·8	1005	589·43	589·42	+0·01	Na
1029·3	1031	585·87	586·05	−0·18	Ca
1031·8	1034	585·53	585·67	−0·14	Ba
1043	1045	583·95	584·28	−0·33	Au
1050	1057	582·91	582·79	+0·12	Ba
1158	1177	568·34	568·56	−0·22	Hg
1200·6	1225	562·95	563·20	−0·25	Fe
1207·3	1236	561·96	562·00	−0·04	Fe
1217·8	1247	560·75	560·62	+0·13	Fe.Ca
1219·2	1249	560 46	560·46	0·00	Ca
1231·3	1261	559·12	559·14	−0·02	Fe
1235	1265	558·65	558·70	−0·02	Ca
1245 6	1276	557·38	557·49	−0·11	Fe
1274 7	1311	553·92	553·75	+0·17	Sr
1301	1341	550·79	550·61	+0·18	Sr
1337	1383	546·72	546·33	+0·39	Fe
1343·5	1391	545·93	545·53	+0·45	Fe
1352·7	1400	544·94	544·64	+0·30	Fe
1385·7	1439	541·33	541·30	+0·03	Cr
1410·5	1467	538·77	538·90	−0·13	Fe
1421·5	1481	537·80	537·67	+0·17	Fe
1430·1	1491	536·63	536·79	−0·17	Co
1440·2	1501·5	535·61	535·86	−0·25	Co
1443·5	1506	535·25	535·45	−0 20	Ca
1506.3	1582	528·77	528·77	0·00	Fe
1523·7	1599·5	527·42	527·37	+0·05	Fe.Ca
1539	1617	526·00	525·96	+0·04	Sr
1566·5	1642	523 87	523·94	−0·07	Co
1575	1651	523·29	523·22	+0·07	Sr
1577·5	1656	523·08	522·83	+0·25	Sr
1582	1659	522·74	522·60	+0·14	Sr
1596	1670	521·63	521·73	−0·10	Co
1601·5	1677	521·31	521·18	+0·12	Cr
1627·2	1702	519·25	519·24	+0·01	Ca
1650·3	1728	517·56	517·26	+0·30	Fe
1769·5	1843	508·77	508·83	−0·06	Cd
1832·8	1907	504·65	504·39	+0·26	Ca
1867·1	1940·5	502·25	501·86	−0·39	Fe
1961	2036	496·11	496·05	+0·06	Fe
1989·5	2075	493·78	493·67	+0·11	Ba
2058	2172	488·40	488·06	+0·34	Ca

Table V (continued).

K	H	Kλ	Hλ	Δ	E
2071·3	2186	487·19	487·29	−0·10	Co
2103·3	2236	484·66	484·48	+0·18	Co
2132·3	2286	482·00	481·80	+0·20	Co
2148·5	2315	480·56	480·27	+0·29	Cd
2157·4	2325	479·76	479·70	+0·06	Co
2626·5	3156	444·61	444·45	+0·16	Pt
2668·5	3239	441·90	441 75	+0·15	Cd
2721·6	3341	438·75	438·55	+0·20	Fe
2822·3	3532	432·82	432·75	+0·07	Fe
2834·2	3561	431·77	431·92	−0·15	Ca
2854·7	3597	431·03	430·92	+0·11	Fe
2864·7	3617	430·79	430·36	+0·43	Ca
2869·7	3628	430·21	430·05	+0·36	Ca

In this table K represents the scale number upon Kirchhoff's scale, H that upon Mr. Huggins's scale, Kλ and Hλ the corresponding wave lengths, and Δ their difference. An examination of this table will show, I think, upon the whole, a very satisfactory correspondence. For the portion of Mr. Huggins's scale beyond G I have been obliged to rely upon my unassisted judgment for identification, as Kirchhoff's scale does not extend much farther than this point. This is therefore probably the least reliable portion of my work, though as yet I have seen no reason to doubt its accuracy. For the portion of the scale between A and C we possess very few measurements of wave lengths, and I have therefore postponed its discussion until more ample materials should be at hand. To form a correct estimate of the degree of accuracy to be obtained by interpolation in cases like the one before us, it is desirable to compare with each other the measurements of wave lengths made by different observers. To facilitate this comparison as much as possible, I have brought together in tables VI and VII all the measurements of wave lengths which I have been able to find, with the exception of a few isolated cases.

This table contains measurements by Van der Willigen,* Angström† and Ditscheiner,‡ with columns of differences for convenience of reference. Column first contains the numbers denoting the lines measured by Van der Willigen; column second, the corresponding numbers on Kirchhoff's scale; column third, Angström's measurements, reduced to millionths of a millimeter; column fourth, the measurements of Van der Willigen; column fifth, Ditscheiner's measurements, reduced for the value of D_2, given by Angström; column sixth, Ditscheiner's measurements, as given in his second paper,§ in which the absolute value of the interval between two successive

* Archives du Museè Teyler, vol. i, p. 1. † Pogg. Ann., cxxiii, p. 489.
‡ Sitzungsberichte der k. k. Akad. der Wissenschaften, Bd. l, 1864.
§ Band lii, 289.

Note.—I have not been able to find in any public library in this country a copy of the Annales Scientifiques de l'ecole normale supérieure à Paris, vol. iv, containing an extended memoir on wave lengths by Mascart.

TABLE VI.

V.D.W.	K.	Ang. λ.	V.D.W.λ.	Ditsch.λ1.	Ditsch.λ2.	A.and V.D.W.	A.andD.1.	A.andD.2.	V.D.W. and D.1.
4a	593	687·49	687·48	687·81	688·33	+0·01	−0·32	−0·84	−0·33
5	694	656·76	656·56	656·77	657·11	+0·20	−0·01	−0·35	−0·21
6	711·5	-----	651·94	652·09	652·58	---	---	---	−0·15
7	719·5	-----	649·77	650·05	650·54	---	---	---	−0·28
9	850	619·17	619·45	619·72	620·09	−0·28	−0·55	−0·92	−0·27
10	864	616·33	616·49	616·73	617·19	−0·16	−0·40	−0·86	−0·24
11	877	614·31	613·96	614·24	614·70	+0·35	+0·07	−0·39	−0·28
12	885	612·34	612·52	612·76	613·22	−0·18	−0·42	−0·88	−0·24
13	895	610·45	610·52	610·82	611·28	−0·07	−0·37	−0·83	−0·32
14a	1002·8	590·04	589·86	590·07	590·53	+0·18	−0·03	−0·49	−0·21
14γ	1006·8	589·43	589·26	589·43	589·89	+0·17	0·00	−0·46	−0·17
15	1200·4	-----	562·70	562·97	563·39	---	---	---	−0·27
16	1207	561·99	561·80	561·98	562·40	+0·19	+0·01	−0·41	−0·18
17	1280	-----	553·19	553·27	553·68	---	---	---	−0·08
18	1324·8	-----	547·86	548·13	548·54	---	---	---	−0·27
19	1343	545·97	545·83	546·05	546·46	+0·14	−0·08	−0·49	−0·22
20	1421·6	-----	537·38	537·52	537·92	---	---	---	−0·14
21	1463	533·16	533·05	533·29	533·69	+0·11	−0·13	−0·53	−0·24
22a	1523·5	527·32	527·24	527·38	527·83	+0·08	−0·06	−0·51	−0·14
23	1569·8	523·69	523·50	523·74	524·13	+0·19	−0·15	−0·44	−0·24
24	1577·5	-----	522·96	523·09	523·49	-----	-----	-----	−0·13
25	1634	518·79	518·63	518·73	519·12	+0·16	+0·03	−0·33	−0·10
26	1648·8	517·66	517·51	517·70	518·09	+0·11	−0·04	−0·43	−0·19
27β	1655·6	517·15	517·07	517·15	517·54	+0·08	0·00	−0·39	−0·08
28	1750·4	-----	510·18	510·30	510·68	-----	-----	-----	−0·12
29	1777·4	-----	508·27	508·41	508·79	-----	-----	-----	−0·14
30	1834	-----	504·37	504·55	504·93	-----	-----	-----	−0·18
31	1961	-----	496·01	496·15	496·53	-----	-----	-----	−0·14
32	2041·4	489·50	489·38	489·54	489·90	+0·12	−0·04	−0·40	−0·16
33	2067	487·55	487·46	487·55	487·91	+0·09	0·00	−0·36	−0·09
34	2080·1	486·52	486·39	486·49	486·87	+0·12	+0·03	−0·35	−0·10
35	2309	-----	467·00	467·07	467·42	-----	-----	-----	−0·07
36a	2489·4	-----	453·75	453·73	454·09	-----	-----	-----	+0·02
37	2721·6	438·63	438·58	438·75	439·08	+0·05	−0·12	−0·45	−0·17
38	2797	434·28	434·28	434·34	424·66	0·00	−0·06	−0·38	−0·06
39	2822·8	432·78	432·74	432·82	433·14	+0·04	−0·04	−0·36	−0·08
40	2854·7	431·03	431·12	431·35	431·70	−0·09	−0·32	−0·67	−0·23
H	-----	397·16	397·13	397·10	397·42	+0·03	+0·06	−0·26	+0·03
H_1	-----	393·59	393·76	393·74	394·05	−0·17	−0·15	−0·46	+0·02

lines on the ruled glass surface employed was determined. The other columns exhibit the differences between the first and second, first and third, first and fourth, and second and third series of measurements.

In table VII, I have given the measurements of the wave lengths of the eleven principal lines of Fraunhofer made by different observers. The differences, as will be remarked, are rather large, but it must be borne in mind that the breadths of the lines themselves is probably one source of error,—different observers measuring different parts of the same line.

In my second discussion of Kirchhoff's scale, I have divided the observations into twelve groups, giving weights to all the measurements of wave lengths, and assigning the probable error in the case of each group as well as the values of the con-

TABLE VII.

	Fraunhofer.	Ditscheiner 1.	Ditscheiner 2.	Angstrom.	v. d. Willigen.	Mascart.	Bernard.	Stefan.
A	-----	-----	-----	761·20	763·36	-----	760·6	759·8
B	687·85	687·81	688·33	687·49	687·48	686·66	686·9	687·2
C	655·63	656·66	657·11	656·77	656·56	656·07	656·1	655·8
D	-----	590·07	590·53	590·04	589·86	589·43	----	589·4
D	588·77	-----	589·89	589·43	589·26	588·82	588·8	----
E	526·51	527·42	527·83	527·38	527·24	526·79	526·8	525·3
b	-----	517·70	518·09	517·66	517·51	517·06	----	518·7
F	485·63	486·49	486·87	486·52	486·39	485·98	485·9	484·3
G	429·60	431·35	431·70	431·03	431·12	430·76	430·6	430·2
H	396·30	397·10	397·42	397·16	397·13	396·72	396·8	----
H_1	-----	393·74	394·05	393·59	393·76	-----	----	----

stants deduced for each portion of the scale. Unfortunately, several errors have crept into the table of constants ; these I will correct in this place, giving the proper values in table VIII.

TABLE VIII.

	1	2	*a*	*b*	*c*	*d*	*e*
1	694·1	877	656·65	−26·325	+1·0490	+0·3618	------
2	877	1135·1	614·19	−17·670	−5·5610	+4·6196	−0·8913
3	1135·1	1303·5	571·47	−14·008	+1·5466	−0·3707	------
4	1303·5	1421·5	550·82	−12·842	+2·1860	−0·7367	------
5	1421·5	1577·6	537·49	−10·063	−0·6920	+0·7960	------
6	1577·6	1750·4	523·09	− 8·125	+0·8911	−0·2463	------
7	1750·4	1920·2	510·30	− 6·792	−0·1661	+0·1180	------
8	1920·2	2067·1	498·76	− 5·029	−4 2235	+1·6624	------
9	2067·1	2250·0	487·56	− 8·7225	------	------	------
10	2250·0	2547·2	471·24	− 7·048	------	------	------
11	2547·2	2721·6	449·67	− 6·154	−0·4536	+0·2028	------
12	2721·6	2869·7	438·68	− 7·028	+2·1490	+1·5740	−1 6350

By means of these constants the wave lengths of all the metallic lines upon Kirchhoff's chart have been computed. These are given in table IX.*

TABLE IX.

CALCIUM.		K	λ
K	λ	1221·6	560·24 (5d)
717·8	650·47 (2b)	1224·9	559·87 (5d)
720·1	649·88 (2c)	1228·3	559·42 (2d)
729	647·60 (2b)	1229·6	559 27 (4c)
731·7	646·93 (5b)	1235	558·62 (3d)
736·9	645·60 (3b)	1443·5	535·25 (2b)
740·9	644·60 (5b)	1522·7	527·40 (6c)
840	621·81	1528·7	526·88 (5c)
844·5	620 90	1530·2	526·75 (4c)
848	619·95	1532·5	526·55 (4b)
849·5	619·54	1533 1	526·49 (4b)
855	618·54	1627·2	519·24 (5b)
857·5	618·03	1832·8	504·66 (2a)
860·2	617·50 (3d)	2058	488·40 (6c)
863·9	616·78 (5b)	2606·5	445·93 (5c)
884·9	612·94 (4b)	2638·5	443·89 (4e)
891·9	610·83	2653	442·96 (1d)
941·5	602·56	2834·2	433·01 (5c)
943	602·26	2855 2	431·56 (4)
1029·3	585·87 (3c)	2864·7	430·79 (4b)
1217·8	560·69 (5d)	2869·7	430 21 (5c)
1219·2	560·53 (3c)		

BARIUM.		K	λ
K	λ	1269·5	554·52
718·7	650·24 (2)	1274·7	553·90 (3a)
874·3	614·78 (4b)	1286	552·57
880·2	611·75 (1b)	1301	550·83
903·5	609·17	1317	549·11
934	603·08	1320·6	548·68 (4c)
964·5	597·05	1539	525·98
1031·8	585·51 (2a)	1562	524·18
1050	582·88	1575	523·24
1083	578·51 (2a)	1578·5	522 97
1274·2	553 96 (3b)	1582	522·71
1287·5	552·40 (1c)	2385·5	461·69
1371·4	542·87 (1b)	2386·6	461 62 (2a)
1989·5	493·78 (6c)	2858·5	431·38 (4a)
2031·1	490·20 (2c)	2860	431·18 (1)
2461·2	456·36 (6b)		
2502·3	453·46 (4c)		

STRONTIUM.	
K	λ
717·5	650·68
753·8	641·38 (3b)

MAGNESIUM.	
K	λ
1634·1	518·73 (6g)
1649	517·64 (6f)
1655·9	517·17 (4d)

* In this table the intensities of the lines are denoted on an increasing scale by the numbers 1, 2, 3, 4, 5, 6, and the breadths by the letters a, b, c, d, e, f, g, so that a denotes the least and g the greatest breadth.

TABLE IX (continued).

K	λ
2414·8	459·62 (2b)
2565	448·57 (6c)
2568	448·39 (3b)

SILVER.

K	λ
1330	547·55
1335	546·96
1600	521·32

GOLD.

K	λ
809·5	628·23 (3b)
967	596·57
969·6	595·08 (3a)
1042·5	583·95
1572	523·46
2157	479·76 (3a)

ANTIMONY.

K	λ
798·1	630·84 (3a)
824·5	624·92
881	613·50 (1a)
906·1	608·69 (2c)
919	606·10
942	601·46
957·2	598·41
994	591·61 (1b)
997·1	591·09 (2b)
1002·7	590·22
1004·8	589·76
1187·1	564·54 (2a)
1189	564·28'
1245	557·42
1247	557·19
1334	547·08 (4b)
1338	546·61
2252	471·10
2254	470·86

ARSENIC.

K	λ
860	617·54
890·5	611·69
932·5	603·38 (4b)
1179·4	578·95 (1a)
1254·5	558·29
1304·5	550·42
1458	538·75
1460·5	533·55
1600	521·32

CHROMIUM.

K	λ
1385·7	541·35 (5b)
1601·4	521·20 (6b)
1604·4	520·98 (5b)
1606·4	520·83 (5b)

COPPER.

K	λ
1081·8	578·67 (2b)
1497·3	529·30 (1a)
1588·3	522·24 (1g)
2329·5	465·64

CADMIUM.

K	λ
730·5	647·22
740·9	644·59 (5b)
1453·7	531·27
1769·5	509·00
2148	480·56
2294·5	468·10 (2b)
2667·7	441·94

MERCURY.

K	λ
869·2	537·67 (2b)
1090·5	577·54
1092·5	577·28
1157	568·47
1161	567·94 (2a)
1338	546·61
1340·5	546·33
1369	543·13
1372	542·80
2777	535·45 (2)
2779	535·36 (2)

LEAD.

K	λ
735	646·09
923	605·29 (2b)
924	605·09
944	601·00
1213	561·29
1263	555·29
1266	554·93
1419·5	537·71
1826	505·13
1822	504·71
2714	439·18
2716	439·07

TIN.

K	λ
736	645·83
1070	615·59
1250	556·83
1252	556·59
1748	510·55
2417	459·47
2503	453·41

IRON.

K	λ
721·1	649·62 (2b)
756·9	640·60 (5b)
798·5	630·53 (4a)
831	623·52 (4c)
849·7	619·60 (3c)
877	614·27 (4c)
912·1	607·48 (3b)
931·3	603·62 (4b)
991·9	591·95 (3b)
1096·1	576·79 (3c)
1200·6	562·83 (4b)
1207·3	561·99 (5g)
1217·8	560·71 (5d)
1231·3	559·06 (5d)
1239·9	558·01 (4a)
1242·6	557·71 (6c)
1245·6	557·35 (4d)
1337	546·72 (4d)
1343·5	545·98 (6c)
1351·1	545·12 (5d)
1352·7	544·93 (5b)
1362·9	543·80 (5b)
1367	543·34 (6d)
1372·6	542·74 (5b)
1380·5	541·89 (4c)
1384·7	541·44 (4c)
1389·4	540·93 (6c)
1390·9	540·78 (5d)
1397·5	540·07 (5c)
1401·6	539·63 (4c)
1410·5	538·68 (4c)
1421·5	537·51 (6c)
1423	537·32 (5b)
1425·4	537·11 (5b)
1428·2	536·81 (5b)
1450·8	534·50 (5c)
1451·8	534·40 (5b)
1462·8	533·26 (5c)
1463·3	533·21 (5c)
1466·8	532·96 (5c)
1473·9	532·13 (5b)
1487·7	530·75 (5b)
1506·3	528·93 (5c)
1508·6	528·76 (5b)
1522·7	527·41 (6c)
1523·7	527·32 (6c)
1527·7	526·98 (5c)
1569·6	523·63 (5c)
1577·2	523·07 (5c)
1622·3	519·62 (5c)
1623·4	519·53 (5b)
1650·3	517·55 (6b)
1653·7	517·31 (6b)
1655·6	517·16 (6c)
1662·8	516·67 (5b)
1693·8	514·47 (6e)
1701·8	513·87 (5c)
1867·1	504·33 (5d)
1961·2	496·11 (6b)
2001·6	492·76 (5c)
2005·2	492·44 (6d)
2007·2	492·27 (6c)
2041·3	489·42 (6c)
2042·2	489·35 (6b)
2058	488·14 (6c)
2066·2	487·55 (5c)
2067·1	487·49 (5c)
2082	486·42 (6a)
2670	441·88 (6c)
2686·4	440·85 (6f)
2721	438·75 (6)
2822·3	438·61 (6)
2854·7	431·61 (6)

ZINC.

K	λ
771·8	636·99 (1a)
893	611·21
896	610·64
930	603·88
933	603·27
1004	589·90
1996	493·23
2000·5	492·85
2013·5	492·73
2018	491·34
2136	489·88 (5a)
2240	472·25 (3b)
2291·8	468·29 (2g)

COBALT.

K	λ
873	615·02
884·9	612·75 (4b)
942	601·46
1319	550·11 (3c)
1346	545·70
1354·5	544·74
1424	537·25
1429·8	536·65
1433	536·32
1438·9	535·72 (4c)
1440·2	535·59 (1b)
1448·7	534·71 (2a)
1449·4	534·54 (1a)
1510·3	528·55 (2c)
1525	527·20 (1b)
1527·7	526·96 (5c)
1566·5	523·86 (2b)
1572	523·46
1596	521·63
2071·3	487·19 (1b)
2103·3	484·66 (4b)
2132·3	482·00 (2a)
2157	479·76 (3a)
2171·5	478·32 (3b)
2206·4	475·59 (1a)
2422·3	459·10 (6d)
2493·6	454·07 (5a)

PLATINUM.

K	λ
709·3	652·67
949	600·07
952·5	599·38
953·2	599·34
954·5	599·00
956·4	598·57
958·5	598·22
965·5	596·86
970·5	595·90 (1b)
972	595·62
1325·7	548·07 (1)
1488·2	530·70 (3)
1489	530·62 (3)
1576·8	523·10 (1)
1806·1	506·49 (2)
1806·9	506·43 (2)
2057	488·22 (1)
2463·4	456·19 (4b)
2540·5	450·77 (2g)
2626·3	445·65 (2a)

RUTHENIUM AND IRIDIUM.

K	λ
778·3	635·45
1348·3	545·44 (1b)
1489·9	530·52 (1a)

TABLE IX (continued).

NICKEL.

K	λ	
856·8	618·19	(2a)
857	618·10	(2a)
887·7	612·23	(2a)
891·7	611·47	(2a)
1005	589·73	(2b)
1029·3	585·87	(3c)
1324·8	548·17	(4d)
1643	518·08	(1b)
1653·7	517·30	(6b)
1672·2	515·97	(4a)
1684	515·28	(4a)
1690	514·71	(5b)
1697	514·21	(5c)
1727·3	512·05	(3b)
1748·9	510·48	(3c)
1749·6	510·43	(2d)
1775·8	508·57	(3b)
1776·5	508·52	(3c)
1842·2	504·02	(4b)
1868·4	502·25	(5b)
1920·2	498·76	(4b)
1925·8	498·50	(4b)
1987·5	493·87	(3a)
2008·1	492·19	(1b)
2025·7	490·59	(4a)
2064·7	487·66	(2c)
2073·5	487·03	(3b)
2086·9	485·97	(3b)
2112·7	483·82	(3b)
2115	483·56	(3a)
2164	479·16	(4a)
2199·2	476·21	(3a)
2249·7	471·26	(6a)
2334·1	405·31	(2d)

CERIUM.

K	λ	
1190·1	564·15	1
1249·9	556·84	1
1256·7	556·03	1
1329·1	547·65	2
1332·4	547·27	2
1336·2	546·82	1
1385·0	541·40	2
1401·7	539·62	2
1438·9	535·72	3
1460·9	533·46	1
1517·9	527·84	3
1571·0	523·54	1
1572·4	523·43	

K	λ	
1573·0	523·39	2
1623·1	519·56	1
1629·2	519·10	2
1630·4	519·01	
1683·1	515·20	1
1725·5	512·18	1
1777·5	508·45	2
1782·4	508·12	1
1784·5	507·97	
1938·8	497·68	2
2052·3	488.56	1
2231·5	474·23	1

DIDYMIUM.

K	λ	
1225	559·83	2
1230	559·22	1
1364·5	544·62	1
1365·2	544·55	
1431·9	536·44	1
1471·1	532·42	1
1518·6	527·78	1
1519·4	527·71	
1536	526·24	1
1541·4	525·79	1
1548·9	525·18	2
1567·5	523·79	1
1709·2	513·35	2

LANTHANUM.

K	λ	
1411·6	538·56	2
1412·8	538·43	
1416·8	538·00	2
1451	534·48	1
1606·8	520·80	2
1627·9	519·20	2
1634·8	518·69	2
2136·8	481·59	1

LANTHANUM AND DIDYMIUM.

K	λ	
1025	586·52	1
1064·5	580·97	1
1066·1	580·72	1
1071·1	580·06	1
1075·6	579·47	1
1077	579·28	1
1092·1	577·33	2

K	λ	
1302	550·74	1
1303·4	550·60	2
1317·6	549·05	1
1345·4	544·62	1
1486·8	530·84	2
1489·2	530·60	
1622·3	519·62	1
1623·3	519·55	1
1716·6	512·82	2
1728·8	511·95	2
1894·5	500·52	2
1895·2	500·48	
1903	499·97	1
1940·2	497·60	1
1988·6	493·86	1
1989·5	493·78	
2003·8	492·56	2
2004·7	492·49	2
2031	490·25	2
2081	486·49	2
2121·4	483·02	1
2208·2	475·44	2
2214·5	474·87	2
2217·8	474·57	2
2646·2	443·39	

ATMOSPHERIC LINES.

K	λ
711·4	652·13
948	600·27
949·4	599·99
949·8	599·91
951·7	599·54
954·2	599·05
958·8	598·15
959·6	598·00
961·9	597·56
963·7	597·20
964·4	597·06
965·7	596·81
968·7	596·23
969	596·18
969·6	596·06
970·5	595·90
972·1	595·60
974·3	595·18
975	595·05
975·7	594·93
976·1	594·85

K	λ	
977·4	594·60	
977·7	594·54	
982·0	593·75	
982·3	593·70	
988·9	592·51	
989·2	592·45	
989·6	592·38	
993·1	592·77	
993·4	592·73	
998·1	590·90	
999·2	590·70	
1000	590·57	
1001·4	590·33	
1005·8	589·60	
1008·3	589·17	
1009·2	589·02	
1010·5	588·81	
1013·9	588·26	
1015·1	588·07	
1016·4	587·86	
1017·7	587·65	
1018·2	587·57	

PALLADIUM.

K	λ	
1114·7	574·36	1
1146·2	569·94	2
1164·9	567·42	2
1185·6	564·66	1
1264·6	555·10	2
1269	554·58	2
1279·1	553·39	1
1400	539·80	2
1407	539·06	
1430·1	536·62	1
1447·0	534·89	1
1477·0	531·82	1
1495·2	530·01	3
1540	525·90	1
1566·5	523·86	2
1567·1	523·82	
1601·4	521·21	1
1660	516·85	3
1660·7	516·80	
1732·9	511·65	2
1801·9	506·78	1
2062	487·76	2
2123·6	482·81	2
2162	479·33	2

As it is important to be able to judge of the probable error in the determination of each of these lines, I reprint, for the sake of convenience, the table of data employed and differences obtained given in my paper on the determination of wave lengths by the method of comparison. In this reprint, two or three trifling errors have been corrected.

I have already called attention to the very large probable error (±0·66) in the tenth group of observations discussed. That it may not be supposed that I have too hastily adopted a straight line as most nearly representing the data assumed, I will here give the successive orders of differences corresponding to parabolas of the 2d, 3d, 4th and 5th degrees, which I have endeavored to draw through the same points.

TABLE X.*

N	W	K	λ	Δ	ε
1	9	694·1	656·65	0 00	
2	2	711·4	652·07	−0·06	
3	2	719·6	650 03	+0·02	
4	1	783·8	634·23	+0·08	
5	4	831·0	623·59	+0·08	
6	4	849·7	619·60	0·00	
7	7	860·2	617 48	0·00	
8	8	863·9	616·71	−0·04	
9	6	874·3	614·72	0·00	
10	9	877·0	614·23	0·00	± 0·04
10	9	877·0	614·23	+0·05	
11	7	884·9	612·75	0·00	
12	7	894·9	610·80	−0·06	
13	2	958·8	598·12	−0·02	
14	11	1002·8	590·07	−0·05	
15	18	1006·8	589·43	−0·02	
16	4	1012·3	586·25	+0·35	
17	3	1096·1	576·71	−0·13	
18	3	1102·9	575·77	−0·18	
19	8	1135·1	571·49	+0·06	± 0·13
19	8	1135·1	571·49	0·00	
20	2	1155·7	568·69	+0·02	
21	10	1174·2	566·32	+0·09	
22	5	1200·6	562·95	+0·07	
23	16	1207·3	561·96	−0·08	
24	9	1217·8	560·75	0·00	
25	8	123·13	559·12	0·00	
26	7	1242·6	557·76	0·00	
27	10	1280·0	553·25	−0·06	
28	1	1303·5	551·11	+0·59	±0·16
28	1	1303·5	551·11	+0·28	
29	2	1306·7	550·68	+0·26	
30	12	1324·8	548·11	−0·07	
31	3	1337·0	546·76	+0·02	
32	8	1343·5	546·03	+0·04	
33	5	1351·1	545·06	−0·07	
34	10	1367·0	543·40	+0·04	
35	11	1389·4	540·90	−0·04	
36	1	1410·5	538·77	+0·09	
37	9	1421·5	537·50	0·00	±0·12
37	9	1421·5	537·50	0·00	
38	9	1450·8	534·49	−0·02	
39	18	1463·3	533·27	+0·04	
40	6	1492·4	530·21	−0·09	
41	6	1506·3	528·77	−0·18	
42	7	1515·5	527·99	+0·10	
43	9	1523·7	527·42	+0·07	
44	2	1541·9	525·97	+0·20	
45	8	1569·6	523·72	+0·05	
46	8	1577·6	523·08	−0·05	±0·08
46	8	1577·6	523 08	−0·01	
47	1	1589·1	521·96	−0·21	
48	6	1601·7	521·31	+0·12	
49	4	1622·3	519·65	+0·03	
50	18	1634·1	518·71	−0·03	
51	14	1648·8	517·68	+0·01	
52	13	1655 6	517·13	−0·05	
53	6	1693·8	514·63	+0·16	
54	4	1737·7	511·41	+0·05	
55	4	1750·4	510·28	−0·16	±0·10
55	4	1750·4	510·28	−0·02	
56	6	1777·5	508·39	−0·02	
57	5	1799·0	506·89	−0·04	
58	13	1834·3	504·54	+0·03	
59	5	1854·9	503·24	+0·12	
60	5	1867·1	502·25	−0·05	
61	2	1873 4	501·66	−0·23	
62	7	1885 8	501·05	−0·01	
63	4	1908·5	499·70	+0 12	
64	6	1920·2	498·76	−0·07	±0·08
64	6	1920·2	498 76	0·00	
65	17	1960·8	496·14	+0·01	
66	2	1975·7	495·03	+0·08	
67	7	1983 3	494·33	0·00	
68	6	1989·5	493·75	−0·05	
69	7	2005·2	492 31	−0·15	
70	3	2018·5	491·39	+0·07	
71	9	2041·3	489·52	+0·09	
72	2	2058·0	488·16	0·00	
73	9	2067·1	487·53	0·00	±0·06
73	9	2067·1	487·53	−0·03	
74	21	2080·0	486·49	+0·06	
75	1	2103·3	484·62	+0·32	
76	8	2119·8	482·80	−0·16	
77	1	2148·9	480·54	+0·23	
78	1	2157·4	479·53	−0·03	
79	3	2160·6	479·21	−0·19	
80	6	2187·1	476·92	−0 18	
81	3	2201·9	475·89	+0·09	
82	2	2221·7	474·33	+0·22	
83	5	2233·5	473·35	+0·30	
84	2	2250 0	471·24	−0·38	±0·14
84	2	2250·0	471·24	+0·02	
85	4	2264·3	470·69	+0·05	
86	12	2309·0	467·06	−0·02	
87	5	2416·0	460 61	+1·06	
88	5	2436·5	458·65	+0·34	
89	3	2457·5	456·80	+0·18	
90	6	2467·6	455·70	−0·20	
91	8	2489·4	453·71	−0·66	
92	2	2537·1	450·54	−0·46	
93	1	2547·2	450·12	−0 17	±0·66
93	1	2547·2	450·12	+0·44	
94	9	2566·3	448·45	−0·05	
95	7	2606·6	445·99	+0·05	
96	4	2627·0	444·63	0·00	
97	7	2638·6	443·83	−0·05	
98	8	2670·0	441·87	−0 01	
99	7	2686·6	440·86	+0·01	
100	12	2721·6	438·74	0·00	±0·15
100	12	2721 6	438·74	+0·15	
101	7	2734·9	437·79	+0·09	
102	8	2775·7	435·66	+0·14	
103	11	2797·0	434·32	−0·33	
104	11	2822·8	433·80	+0·23	
105	17	2854·7	431·34	−0·25	
106	7	2869·7	430·36	+0·26	±0·24

* In this table the column W gives the weights for the different wave lengths.

$\Delta^2\lambda$	$\Delta^3\lambda$	$\Delta^4\lambda$	$\Delta^5\lambda$
+0·02	+0·48	−0·46	−1·04
+0·05	+0·34	−0·13	−0·24
−0·02	−0·19	−0·12	+0·25
+1·06	+0·69	+0·57	+0·19
+0·34	+0·04	−0·17	−0·39
+0·18	+0·04	−0·21	−0·13
−0·20	−0·25	−0·47	−0·27
−0·66	−0·48	−0·51	−0·12
−0·46	+0·38	+1·58	+1·27
−0·17	−0·85	+2·41	+1·46

These differences are sufficient to show that a straight line gives, upon the whole, the best representation of the observations, but that in all probability the form of the function to be assumed for the purpose of interpolation is not parabolic. The same remark applies, though in a much less degree, to the ninth group. In this case the successive differences are as follows:—

$\Delta^2\lambda$	$\Delta^3\lambda$	$\Delta^4\lambda$	$\Delta^5\lambda$
−0·03	+0·04	+0·13	+0·25
+0·06	+0·08	+0·07	0·00
+0·32	+0·25	+0·17	+0·12
−0·16	−0·27	−0·36	−0·29
+0·23	+0·09	+0·08	+0·25
−0·03	−0·16	−0·15	−0·01
−0·19	−0·32	−0·30	−0·17
−0·18	−0·27	−0·19	−0·27
+0·09	+0·06	+0·14	−0·09
+0·22	+0·28	+0·30	+0·10
+0·30	+0·43	+0·37	+0·31
−0·38	−0·15	−0·38	+0·20

In computing the wave lengths of the lines on Kirchhoff's scale between the scale numbers 2067·1 and 2250·0, a parabola of the 5th order was employed, because this distributes the errors rather more evenly than the straight line the constants for which are given for group 9 in table VIII. The probable error is about the same in both cases.

To complete my work, it remains for me to show to what extent the wave lengths calculated by the two wholly independent processes of interpolation, with different data, agree with each other. Table XI contains all the lines for which the wave lengths can be determined for both scales.

In this table columns K and H give the scale numbers upon Kirchhoff's and Huggins's scales, respectively; columns Kλ and Hλ the corresponding wave lengths, and column Δ, their differences. An impartial examination of this table—which of course includes table V—will show, I think, as close an agreement as can be reasonably expected. The differences between the wave

Table XI.

Calcium.

K	H	Kλ	Hλ	Δ
717·8	622	650·47	650·34	+0·13
720·1	625	649·88	649·77	+0·11
729	637	647·60	647·47	+0·13
731·7	642	946·93	646·51	+0·42
736·9	649	645·60	645·17	+0·43
740·9	655	644·60	944·03	+0·57
860·2	813	617·50	617·51	−0·01
863·9	818	616·78	616·67	+0·11
884·9	843	612·94	612·78	+0·16
894·9	859	610·83	611·06	−0·23
1029·3	1031	585·87	586·05	−0·18
1219·2	1247	560·53	560·65	−0·12
1221·6	1219	560·24	560·39	−0·15
1228·3	1258·5	559·42	559·42	0·00
1229·5	1260	559·27	559·27	0·00
1235	1265	558·62	558·59	−0·03
1443·5	1506	535·25	535·45	−0·20
1522·7	1599·5	527·40	527·36	+0·04
1528·7	1605	526·88	526·93	−0·05
1532·5	1609	526·55	526·61	−0·06
1627·2	1702	519·24	519·24	0·00
1832·8	1907	504·66	504·40	+0·26
2606·5	3124?	445·93	455·49	+0·44
2638·5	3181	443·89	443·64	+0·25
2653	3212	442·96	442·66	+0·30
2855·2	3561?	431·56	431·94	−0·38
2864·7	3602·5	430·79	430·79	0·00
2869·7	3617	430·21	430·36	−0·15

Barium.

K	H	Kλ	Hλ	Δ
718·7	621·5	650·24	650·44	−0·20
890·2	847	611·75	612·15	−0·40
934	908	603·08	602·70	+0·38
964·5	943	597·05	597·58	+0·53
1031·8	1034	585·51	585·67	−0·16
1050	1067	582·88	582·77	+0·11
1083	1096	578·51	578·00	+0·51
1274·2	1308	553·95	534·06	−0·11
1287·5	1327	552·40	532·06	+0·34
1989·5	2075	493·78	493·57	+0·21
2031·1	2133	490·20	490·23	−0·03

Mercury.

K	H	Kλ	Hλ	Δ
1157	1177	568·47	568·55	−0·08
1340·5	1385	546·33	546·13	+0·20
1372	1421	542·80	542·80	0·00

Strontium.

K	H	Kλ	Hλ	Δ
763·8	669	641·38	641·39	−0·01
1274·7	1311	553·90	553·74	+0·16
1286	1324	552·57	552·38	+0·19
1301	1341	550·83	550·61	+0·22
1317	1349?	549·11	549·78	−0·67
1320·6	1359	548·68	548·75	−0·07
1539	1617	525·98	525·95	+0·03
1562	1638	524·18	524·26	−0·08
1575	1651	523·24	523·23	+0·01
1578·5	1656	522·97	522·83	+0·14
1582	1659	522·71	522·60	+0·11

Silver.

K	H	Kλ	Hλ	Δ
1330	1372	547·55	547·44	+0·11
1335	1380	546·96	546·63	+0·33
1600	1675	521·32	521·34	−0·02

Gold.

K	H	Kλ	Hλ	Δ
967	951	596·57	596·45	+0·12
969·5	956	596·08	595·75	+0·33
1042·5	1045	583·95	583·38	+0·57
1572	1647	523·46	523·56	−0·10
2151	2326	479·76	479·64	+0·12

Antimony.

K	H	Kλ	Hλ	Δ
798	729	630·84	630·49	+0·35
881	837	613·50	613·73	−0·23
957·5	937·5	598·41	598·72	−0·31
994	988·5	591·61	591·45	+0·16
1004·8	1005	589·76	589·76	0·00
1187	1214	564·54	564·41	+0·13
1247	1279	557·19	557·18	+0·01
1338	1383	546·61	546·33	+0·28
2252	2488	471·10	471·03	+0·07

Arsenic.

K	H	Kλ	Hλ	Δ
860	812	617·54	617·67	−0·13
890·5	850	611·69	611·67	+0·02
1179·5	1090	578·95	578·73	+0·22
1460·5	1529	533·55	533·41	+0·14

Cadmium.

K	H	Kλ	Hλ	Δ
730·5	639	647·22	647·08	+0·14
1453	1517	534·27	534·47	−0·20
1769·5	1843	509·00	508·83	+0·17
2148	2315	480·56	480·27	+0·29
2667·7	3239	441·94	441·81	+0·13

Tin.

K	H	Kλ	Hλ	Δ
736	648	645·83	645·27	+0·56
1748	1821	510·55	510·40	+0·15

Iron.

K	H	Kλ	Hλ	Δ
756·9	673	640·60	640·64	−0·04
831	772	623·52	623·38	+0·14
849·7	795	619·60	619·92	−0·32
1207·3	1236	561·99	561·93	+0·06
1217·8	1247	560·71	560·69	+0·02

TABLE XI (continued).

K	H	Kλ	Hλ	Δ
1231·3	1261	559·06	559·14	−0·08
1239·9	1276?	558·01	557·49	−0·48
1352·7	1400	544·93	544·64	+0·29
1367	1413	543·34	543·37	−0·03
1372·6	1421·5	542·74	542·78	−0·04
1380·5	1434	541·89	541·73	+0·16
1384·7	1438	541·44	541 39	+0·05
1390·9	1445	540·78	540·80	−0 02
1397·5	1456	540·07	539·86	+0·21
1401·6	1459·5	539·63	539·55	+0·08
1421·5	1481	537·51	537·67	−0·16
1423	1485·3	537·32	537·28	+0·04
1425·4	1486·5	537·11	537·18	−0·07
1527·7	1603	526·98	527·09	−0·11
1569·6	1645	523 63	523·70	−0·07
1577 2	1653	523·07	523·09	−0·02
1622·3	1696	519·62	519·70	−0·08
1623·4	1698	519·53	519·55	−0·02
1653·7	1728	517·31	517·25	+0·06
1655·6	1731	517·16	517·03	+0·13
1693·3	1767	514·47	514·33	+0·14
1701·8	1775	513·87	513·74	+0·13
1961	2036	496·11	496·05	+0·06
2001·6	2092	492·76	492·65	+0·11
2007 2	2098	492·27	492·30	−0·03
2041·3	2147	489·42	489·47	−0·05
2886·4	3272	440·85	440·81	+0·04
2822·3	3341	438·61	438·55	+0·06

COBALT.

K	H	Kλ	Hλ	Δ
889·9	844	612·75	612·62	+0·13
1354·5	1401	544·74	544·54	+0·20
1424	1483	537·25	537·50	−0·25
1429·8	1491	536·65	536·79	−0·14
1433	1496	536·32	536·34	−0·02
1438·9	1500·5	535·72	535·75	−0·03
1440·2	1501·5	535·59	535·66	−0·07
1448·7	1514	534·71	534·74	−0·03
1510·3	1584	528·55	528·60	−0·05
1525	1602	527·20	527·17	0·03
1527·7	1604	526·96	527·01	−0·05
1566·5	1642	523·86	523·94	−0·08
1572	1650	523·46	523·31	+0·15
1596	1670	521·63	521·73	−0·10
2071·3	2186	487·19	487·29	−0·10
2103	2236	484·66	484·48	+0·18
2132·3	2286	482·00	481·80	+0·20
2157	2325	479·76	479·70	+0 06

ZINC.

K	H	Kλ	Hλ	Δ
771·8	696	636·99	637·37	−0·38
896	855	610·64	610·89	−0·25
1004	1001	589·90	589·90	0·00
2240	2469	472·25	471·98	+0·27

LEAD.

K	H	Kλ	Hλ	Δ
1213	1240	561·29	561·46	−0·17
1419·5	1479	537·71	537·85	−0·14
2716	329	439·07	438·93	+0·14

lengths on the two scales are due to several causes, which it may be well to analyze. In the first place, the errors for any one line may be in opposite directions, so that the difference Δ, gives their sum. For the same reason, a close coincidence in the values of the wave lengths of the same line may sometimes be due to errors which are in the same direction and which nearly balance each other. Too much importance, therefore, must not be attached either to absolute coincidence in value, or to large differences. Secondly, the measurements will, other things being equal, be most accurate in the case of the lines which are narrowest and most sharply defined, while those which are broad, or nebulous, will give comparatively large errors from the difficulty of determining their true positions upon the scale. Finally, it is to be remarked that a large number of the lines, the wave lengths of which have been determined by interpolation from Kirchhoff's scale, have been, from necessity, taken from the chart, as they are not entered in the accompanying tables. A new and by no means insignificant source of error is thus introduced. In estimating the degree of reliance to be placed upon wave

lengths determined by interpolation, it must be borne in mind that each wave length is calculated by means of a formula, the constants of which are determined from a number of measured wave lengths, which is of course a material advantage. Part of the irregularity of certain portions of Kirchhoff's scale is undoubtedly due to variations in the positions of the prisms. In addition, however, it is possible that the lines of which the wave lengths were measured by Ditscheiner were not always correctly identified with lines upon Kirchhoff's scale. After the most careful study of the whole subject, I am disposed to give the preference to the values of the wave lengths as determined by my discussion of Mr. Huggins's measurements in connection with those of Angström. With the materials obtained as above I have endeavored to determine whether the distribution of the lines corresponding to any one element is subject to any definite law. The solution of this problem was first attempted by Mr. Hinrichs,* who, from data in my judgment far too limited in number, drew the conclusion that the spectral lines in the case of any element are distributed in groups, the lines belonging to any one group being equidistant. This would probably bring the whole subject within the reach of Wrede's theory of absorption,† which is a special application of the principle of interferences. My own study of the subject does not justify the conclusion to which Mr. Hinrichs arrived. Even a cursory examination of the tables of wave lengths which I have given above will serve to show that, in very numerous instances, the distances between two successive spectral lines of the same element is less than the probable error in measuring the wave lengths. As the differences in wave length measure the distances between the lines, the element of uncertainty becomes much too large to permit us to reason with safety upon the data now at our disposal. In the mean time it cannot, I think, be denied that the success with which Wrede's theory explains the absorption bands in nitrous acid and other vapors, gives a certain probability to Mr. Hinrichs's views.

My grateful acknowledgments are again due to Mr. S. P. Sharples, by whom I have been assisted in the whole of my laborious work, with a zeal and skill which demand the fullest recognition.

Cambridge, Dec. 23d, 1868.

P. S. In a memoir presented to the Royal Society, March 2d, 1867, Mr. Airy has given a complete reduction of the numbers upon Kirchhoff's scale to the corresponding values in wave lengths. The high and well deserved reputation of the Astron-

* This Journal, II, vol. xlii, p. 350. † Pogg. Annalen, xxxiii.

omer Royal, lends to whatever comes from his pen a more than ordinary interest and value. Those therefore who like myself have felt convinced that an explanation of the physical cause of the spectral lines of the elements could only be sought in an accurate knowledge of the wave lengths of the lines themselves, will eagerly greet the appearance of Mr. Airy's paper. Under these circumstances it becomes desirable to submit the memoir in question to a critical examination and to determine to what extent it furnishes materials for further investigation.

Mr. Airy's method is simple. Taking the original measures of Fraunhofer for the lines C, D, E, F and G, as the basis of computation, and assuming that the relation between the wave lengths and the numbers upon Kirchhoff's scale can be expressed for the whole scale from C to G by a single function of the form*

$$f_1 = a + bk + ck^2 + dk^3 + ek^4$$

he forms five equations, the solution of which by the method of least squares gives the numerical values of the constants a, b, c, d and e. By means of these constants Mr. Airy constructs a table giving the values of the scale-numbers for every ten units of Kirchhoff's scale, from A to G. The portion of this table between A and C is constructed by extrapolation, the data for A and B not being introduced. I shall not dispute the legitimacy of this process with so great an authority as Mr. Airy; it seems to me unsound in principle and therefore unsafe in practice. After the completion of this part of his work, Mr. Airy became acquainted with Angström's memoir, and with the two papers of Ditscheiner on the wave lengths of the spectral lines upon Kirchhoff's chart. He then decided to base his reduction upon the second series of wave lengths as given by Ditscheiner. In place however of beginning *ab initio* with the new data, Mr. Airy preferred to introduce corrections into the results already obtained, adding also a value for the wave length of Fraunhofer's line B. For the method of making these corrections I must refer to the original paper. They are applied directly and only to the lines B, C, D, E, F and G. The corrected values of the wave lengths of these six lines being obtained, the wave lengths in the table above referred to were then corrected. With these corrections a curve was drawn and the corrections for every 0·01 of k were obtained graphically. Finally, the corrections for all the individual lines were interpolated numerically and applied separately to each computed wave length.

From this it appears that out of the 107 absolute measurements of wave lengths made by Ditscheiner, and by him refer-

* $k = \frac{1}{1000}$Kl and $f_1 = 100000000 \times$Frl.

red to lines upon Kirchhoff's scale, Mr. Airy, in his interpolation, employed only six, the intervals between these amounting respectively to 101·4, 308·7, 520·9, 556·3, 774·7, scale divisions. Through these six points Mr. Airy endeavors to draw a parabola of the 5th order. He then employs the 101 other lines measured by Ditscheiner only to compare with the numerical results given by his single formula.

As Mr. Airy has quietly ignored the existence of my reduction of Kirchhoff's scale read before the National Academy of Sciences in August, 1866, and published in abstract in this Journal for January, 1867, I naturally inferred that his work would prove so much more perfect than my own as wholly and justly to supersede it. The following comparative tables of differences will show, I think, that this is not the case. For the sake of completeness I add a column of differences obtained in my second reduction of Kirchhoff's scale, in which Cauchy's method of interpolation was used, and weights were given to the observations.

TABLE XII.

Airy.	Gibbs 1.	Gibbs 2.	Airy.	Gibbs 1.	
+0·25	+0·03	−0·06	+2·01	+0·01	−0·05
+0·43	+0·24	+0·02	+1·87	−0·18	−0 23
+0·69	−0·02	+0·08	+2·12	+0·02	−0·01
+0·90	−0·08	+0 08	+2·32	+0·07	+0·12
+0·94	−0·15	0·00	+2·13	−0·11	−0·07
+1·03	+0·06	0·00	+2·21	+0·11	+0·01
+1·02	−0·02	−0·04	+2·04	+0·04	+0·08
+1·15	−0·06	0·00	+1·82	−0·14	0·00
+1·22	−0·04	+0·05	+1·62	+0·04	−0·05
+1·31	+0·04	0·00	+1·00	−0·59	−0·15
+1·38	+0·09	−0·06	+1·10	+0·04	+0·07
+0·58	−0·26	−0·02	+0·67	+0·04	+0·09
0·00	+0·05	−0·05	+0·34	+0·02	0·00
+0·01	+0·10	−0·02	+0·27	+0·03	−0 03
+0·44	+0·09	+0·35	−0·02	+0 06	+0·06
+1·00	−0·06	−0·13	−0·53	+0·05	+0·32
+1·04	−0·04	−0·18	−1·39	+0·01	−0·16
+1·25	+0·20	+0·06	−1·90	−0·04	+0·23
+1·23	+0·17	+0·02	−2·46	0·00	−0 03
+1·26	+0·06	+0·09	−2·60	0·00	−0·19
+1·29	+0·15	+0 07	−3·52	+0·49	−0·18
+1·11	−0·01	−0·08	−3·57	+0·12	+0·09
+1·22	+0·10	0·00	−4·01	−0·03	+0·22
+1·22	+0·32	0·00	−4·32	−0·01	+0·30
+1·23	+0·03	0 00	−5·51	−0·26	−0·38
+1·09	−0 03	−0 06	−5·32	−0·08	+0·05
+1·66	+0·25	+0·59	−6·43	−0·20	−0·02
+1·53	+0·09	+0·26	−6·83	+0·01	+1·06
+0·97	−0·05	−0·07	−7·59	−0·85	+0·34
+0·93	+0·05	+0·02	−8·23	+0·10	+0·18
+0·90	+0·09	+0·04	−8·66	−0·14	−0·20
+0·72	+0·10	−0·07	−9·30	+0·38	−0·66
+0·73	0·00	+0·04	−9·53	−0·04	−0·46
+0·56	+0·02	−0 04	−9·30	+0·20	−0·17
+0·57	+0·01	+0·09	−9·65	−0·18	−0 05

TABLE XII (continued).

Airy.	Gibbs 1.	Gibbs 2.	Airy.	Gibbs 1.	Gibbs 2.
+0·43	−0·05	0·00	−9·22	+0·03	+0·05
+0·28	−0·07	−0·02	−9·10	+0·01	0·00
+0·24	0 00	+0·04	−9·01	0·00	−0 05
−0·08	−0·06	−0·09	−8 52	+0·54	−0·01
−0·22	−0·16	−0·18	−8·12	+0·12	+0·01
−0 14	−0·06	+0·10	−7·14	+0·04	0·00
+0·01	+0·08	+0·07	−6·82	−0·22	+0·09
+0 20	+0·18	+0·20	−4·77	+0·11	+0·14
+0·38	+0·26	+0·05	−3·91	−0·04	−0·33
+0·41	+0·21	−0·05	−2·50	−0·04	+0·23
+0·28	−0·05	−0·21	+0·10	−0·57	−0 25
+0·70	+0·25	+0·12	+1·06	+0·21	+0·26
+0·81	+0·09	+0·03			
+0·80	−0 03	−0 03			
+1·04	−0 03	+0·01			
+0·07	−0·11	−0·05			
+1·60	+0·16	+0·16			
+1·78	+0 15	+0·05			
+1·62	−0·12	−0·02			
+1·50	−0·01	−0·03			
+1·83	+0·04	−0·04			
+1·98	+0·05	+0·03			
+2·14	+0·14	+0·12			

In computing the differences between observation and calculation given in this table, it must be borne in mind that Mr. Airy's results are compared with Ditscheiner's second series of wave lengths, while my own are compared with the first, as stated in my paper above referred to.* The greatest difference given by Mr. Airy's formula amounts to not less than 9·65 units, his unit being made to correspond with mine, by placing the decimal point six figures to the right. Now, in the part of Kirchhoff's scale in which this difference occurs, the uncertainty in the position on the scale of the line in question becomes, for a difference of 9·65, not less than 150 scale divisions. One other remark will be sufficient. In all processes of interpolation which are equivalent to drawing curves through points, a certain uniformity of distribution of the + and − signs, or in other words of the excesses and deficiencies given by the formula, is necessary. Mr. Airy's formula, as will be seen by a single glance at the signs in the column of differences, violates even this elementary principle.

It is not an agreeable task to point out defects in the work of another, but in the interest of science I am obliged to declare, that for all the purposes of physical investigation, Mr. Airy's paper, in its present form, has no value whatever.

In the proceedings of the Royal Society, vol. xvii, p. 1, Mr. G. J. Stoney has given, in connection with a very interesting and suggestive paper on the physical constitution of the sun and stars, a table of wave lengths for certain lines upon Kirchhoff's scale. This table is so arranged as to give the scale

* See Table VI.

numbers corresponding to equal intervals expressed in wave lengths, and is based upon Angström's measurements alone. For the sake of completeness, I give this table in full, together with the wave lengths for the same lines, as found by myself by Cauchy's method of interpolation, and the differences. For the sake of comparison I have changed the position of the decimal point in the wave lengths determined by Mr. Stoney, so as to correspond with my own results.

TABLE XIII.

K	Sλ	Gλ	Δ	K	Sλ	Gλ	Δ
719·1 ?	650	650·14	—·14	1527·9	527	526·94	+·06
758·5 ?	640	640·22	—·22	1540·2	526	525·88	+·12
800 ?	630	630·39	—·39	1552·8	525	524·87	+·13
845·5	620	620·71	—·71	1565·5	524	523·96	+·04
855	619	618·54	+·46	1578·3	523	522·97	+·03
860·6	617	617·42	—·42	1591·2	522	522·01	—·01
865·7	616	616·50	—·50	1604·3	521	520·99	+·01
870·9	615	615·40	—·40	1617·5	520	519·98	+·02
876·1	614	614·44	—·44	1630·8	519	518·99	+·01
881·3	613	613·46	—·46	1644·3	518	517·99	+·01
886·6	612	612·44	—·44	1658·3	517	516·97	+·03
891·9	611	611·43	—·43	1673	516	515·92	+·08
897·2	610	609·61	+·39	1762 ?	510	509·52	+·48
948 ?	600	600·26	—·26	1913 ?	500	499·30	+·70
1003	590	590·07	—·07	1950·8	497	496·87	+·13
1009·7	589	589·00	·00	1962·5	496	496·00	·00
1070 ?	580	580·20	—·20	1974·3	495	495·05	—·05
1144 ?	570	570·25	—·25	1986·1	494	494·07	—·07
1199·3	563	562·98	+.02	1998	493	493·06	—·06
1207·4	562	561·98	+·02	2010·2	492	492·01	—·01
1215·6	561	560·97	+·03	2022·6	491	490·95	+·05
1223·8	560	559·97	+·03	2035·2	490	489·91	+·09
1232	559	558·98	+·02	2047·9	489	488·89	+·11
1240·2	558	558·00	·00	2060·8	488	487·95	+·05
1248·4	557	557·01	—·01	2073·7	487	487·03	—·03
1309	550	550·13	—·13	2086·7	486	487·15	—·15
1334·7	547	547	·00	2099·8	485	485·04	—·04
1343·3	546	546	·00	2164 ?	480	479·34	+·66
1352·1	545	545·01	—·01	2292·5 ?	470	468·25	+1·75
1361·2	544	544	·00	2422 ?	460	459·12	+·88
1370·5	543	542·97	+·03	2553·2 ?	450	449·72 ?	+·28
1379·7	542	541·97	+·03	2651·5	443	443·06	—·06
1389	541	540·98	+·02	2667·6	442	442·03	—·03
1398·3	540	539·98	+·02	2683·7	441	441·02	—·02
1407·7	539	538·98	+·02	2699·6	440	440	·00
1417·2	538	537·96	+·04	2715·7	439	439·07	—·07
1426·6	537	536·98	+·02	2732	438	437·95	+·05
1436·1	536	536·01	—·01	2748·8	437	436·89	+·11
1445·6	535	535·14	—·14	2766	436	435·95	+·05
1454·4	534	534·13	—·13	2783·4	435	435·17	—·17
1464	533	533·14	—·14	2801·1	434	434·46	—·46
1473·7	532	532·15	—·15	2819	433	433·77	—·77
1483·8	531	531·13	—·13	2837	432	432·90	—·90
1494·1	530	530·12	—·12	2855	431	431·59	—·59
1504·8	529	529·12	—·12	2873·1	430	429·87	+·13
1516·1	528	528·02	—·02				

Mr. Stoney does not state what method he employed in interpolating; the correspondence between his values and my own is in general very close, though I employed the data obtained by Ditscheiner, in place of those of Angström.*

Cambridge, Jan. 1st, 1869.

ART. XVI.—*On the condition of our knowledge of the Processes in Luminous Flames;* by EUGENE W. HILGARD.

FOR more than half a century after Sir Humphrey Davy's important investigations of the subject of flames, the experiments and explanations of that eminent philosopher have passed, unchallenged and almost unchanged, into text-books and lectures. As regards luminous flames especially, he established the necessity of the presence of a solid incandescent body to produce useful luminosity; and in reference to the flames of hydrocarbons in particular, he suggested that the liberation of carbon in them was owing to the combustion of the hydrogen of the compound in advance of its carbon, the latter being heated to incandescence by an oxhydrogen flame, as it were, and failing to be consumed until all the hydrogen was first oxydized.

It is remarkable that an explanation so directly at variance with the daily experience of blacksmiths, and with a lecture experiment performed even in the most elementary course of chemistry, could so long have passed current; for the decomposition of steam by ignited charcoal into hydrogen and carbonic oxyd gases is an old observation. Nay, most of us who have performed this experiment on the lecture table, have been in the habit of passing the gas through lime water or potash lye, to free it from *carbonic acid* before showing its properties. And yet we were taught, and have ourselves taught, that in the flame, hydrogen burnt first and carbon afterward, and any doubt on the subject was quieted by a reflection about the influence of "chemical mass" on affinity.

When, in 1852, I was a student in the laboratory at Heidelberg, to which Bunsen had then but just been called, the latter suggested to me as an interesting subject of investigation, the composition of the gases in the various portions of the flame; stating at the same time that the prevalent opinion concerning

* It is proper to state here, that since this paper was read before the National Academy of Sciences, all the calculations have been revised and many corrections and alterations have been introduced. The original title was, "On the determination of wave lengths by the method of comparison," and a portion of the memoir has already appeared with this title. This Journal for May, 1868.

the respective affinities of hydrogen and carbon for oxygen were certainly erroneous—that, when mixtures of carbonic oxyd and hydrogen were exploded with oxygen in the eudiometer, the distribution of the latter took place according to some law dependent upon the relative proportions between the combustible gases, and also the amount of oxygen present, but discriminating widely in favor of carbon. The experiments upon which this opinion was based, are probably those given in his "Gasometric Methods" at the conclusion of the chapter on the combustion of gases.

In order to study the processes taking place in the flame, it became necessary to investigate first of all, the composition of the gases in the interior cone, from which the flame derives its substance. I constructed a lamp adapted to the introduction of a suction tube into the flame from below, and made a series of fifteen analyses of the gases so collected at various points of the interior cone of the flames of beef tallow, and of wax. The low temperature known to prevail in this portion of the flame rendered it least adapted to elucidating the mooted question of affinities; but being the generator from which the other portions of the flame are supplied, a knowledge of its component gases was indispensable. My analysis (published in Liebig's Annalen der Chemie und Pharmacie, vol. xcii, p. 129, 1854) showed, however, the existence even in the highest portion of the cone, of free hydrogen with a large excess of carbonic oxyd and carbonic acid; the amount of hydrogen varying but little from base to point, while the carbonic acid increased in about the same ratio as nitrogen, i. e., in proportion to the oxygen entering the flame. Bunsen as well as myself failed, however, to draw the legitimate conclusion from these facts, at the time; the more as, with the materials I used, it was impossible to follow the formation of water by progressive oxydation.

The latter difficulty was avoided by Landolt, who, two years later took up the same subject, the failure of my health having rendered doubtful the prospect of my ever being able to resume it so as to carry out the proposed investigation of the other parts of the flame.

Landolt* used illuminating gas of known composition, and was therefore enabled to determine the deficient factor in my analysis, viz., water. So far as comparable his results in general confirmed mine. He felt compelled by the increase of free hydrogen in the higher parts of the flame examined by him, to assume the occurrence of a reaction between free carbon and (preformed) water; but he also failed to draw the inevitable conclusion as to what *must* happen in the luminous cone.

* Pogg. Ann., vol. xcix, p. 389.

A later research of Lunge* on the composition of the gas contained in the interior cone of the flame of a Bunsen's burner, must have led to the truth of the matter, by showing how little oxygen sufficed to render a flame non-luminous when previously mingled with the gas. I have not seen Lunge's memoir; but he likewise seems to have failed to draw the important conclusion of which his analysis must have contained the elements.

Next, in June, 1860, comes a memoir of Erdmann,† who in discussing the principles upon which his gas-tester (a modification of Bunsen's burner) is based, first distinctly enunciates that according to his experiments, the carbon in a flame is oxydized *before* the hydrogen, and that the separation of carbon upon which luminosity depends, is due to heat alone, as would be the case were the gas passed through a red hot tube.

Finally, eighteen months later, we have an elaborate and elegant research by Kersten,‡ wherein he proves by eudiometric experiments that (at least within the limits of the proportions employed by him) whenever a hydrocarbon is exploded with oxygen insufficient to burn more than the carbon to carbonic oxyd no hydrogen at all is oxydized; but that as between carbonic oxyd and hydrogen, the formation of carbonic acid on one hand and of water on the other depend upon "chemical mass," as Bunsen had already shown.

This question has therefore been peremptorily settled by decisive experiments, as much as eight years since. Yet the latest editions of text-books published in this country, and even those which, like the excellent work of Messrs. Eliot and Storer, claim to represent the latest state of the science, still retain the old error regarding the succession of oxydation.

There is another point which, though I took special pains to demonstrate the facts fourteen years ago, is still incorrectly stated in almost all text-books as well as books of reference. I allude to the definition of the several essentially distinct parts of the flame. *Three* only are usually mentioned, viz., the inner cone, the luminous portion, and the outer, faintly luminous envelop or veil. Yet Berzelius already distinguished the very important fourth part, viz: the blue cup-shaped zone surrounding the base of the flame, which is as sharply defined from the inner cone, as from the outer veil with which it is usually confounded.

That this blue cup is identical with the blue cone of the blowpipe oxydation-flame, is stated by Plattner in the first edition of his work on the blowpipe. Strangely inconsistent with his

* Annalen der Chemie und Pharmacie, vol. cxii, p. 205.

† J. pr. Chem., June, 1860, p. 241. ‡ J. pr. Chem., Dec. 1861, p. 290.

own definition, he nevertheless teaches that the blue cup is formed by the combustion chiefly of carbonic oxyd, produced by the "first and weakest effect of the heat on the fuel"—an assumption as little justified by experiments regarding such action, as was that of the combustion of hydrogen previous to carbon. It is palpably inadmissible in reference to the blue oxydation cone, which is of course identical with the flame of a Bunsen's gas burner—the supply of oxygen being, in both cases, sufficiently great, and so mingled with the entire gas as to suppress the separation of carbon.

The part performed by the blue cup, viz: that of a self-heating retort with walls impervious to oxygen, in which dry distillation is accomplished; its theoretical import, as the counterpart of the luminous portion, where the same gases are burnt with evolution of light, render the neglect with which it has been treated doubly surprising. That it is totally distinct from the outer veil is readily perceived when the eye is protected from being dazzled by means of a screen of the shape and size of the luminous hollow cone. The veil is then seen surrounding the blue cup as well as the higher portions of the flame, and is thus proved to be nothing more than a zone of glowing gas; which of course, however, cannot be strictly defined from the luminous envelop, the oxydation being a gradually progressive one, from the highly luminous central portion to that brownish, semi-transparent zone of transition, where the carbonic oxyd, burning simultaneously with hydrogen, fails to produce its characteristic blue tint because of the excessive temperature existing there. The same is the case when it is burnt by itself from a jet kept at a white heat.*

The inner cone, too, is still incorrectly defined as "the space containing the combustible vapors and gases generated from the wick." This would lead any one to suppose, that the external atmosphere had only the effect of burning off the outside of this gaseous mass, and some text-books have gone far in the graphic delineation of this process. My analyses first proved fourteen years since, that even in a tallow flame, characterized by an excess of fuel over the available oxygen, the percentage of nitrogen gas does not fall below 59 per cent in the lowest part of the flame, and increases to 76 per cent at the point of the inner cone, with from 10 to 15 per cent of carbonic acid. The products and educts of combustion therefore greatly exceed the combustible gases and essentially modify the processes thereafter occurring, for it is clear that in the luminous portion, the water and carbonic acid must in part at least again yield up their oxygen, before final combustion.

* See Gmelin's Handbook, art. Carbonic Oxide.

On the latter point, I have never been able to agree with Bunsen, who maintained that the combustion of the carbon in the luminous envelop must be effected by free oxygen penetrating into it; because its combustion at the expense of the reduction of carbonic acid and water, could not be the cause of such intense production of light and heat; and upon his authority, I reluctantly adhered to this view in my paper, above referred to. I believe with Kersten (l. c., p. 314), that the burning surface of the luminous cone, where carbonic oxyd and free hydrogen meet the oxygen of the air, is the sole source of the heat which causes the intense ignition of the interior, and that the oxydation of the free carbon is effected only through the medium of the intensely heated carbonic acid and steam which penetrate from the outside. I habitually compare the process taking place in the luminous envelop, to what would happen if illuminating gas were passed through an ignited tube into which steam and carbonic acid are injected through lines of lateral orifices. The ignited carbon set free by heat would render the interior atmosphere intensely luminous at the near end, but the luminosity would rapidly decrease toward the far end, where we would have such a mixture of carbonic oxyd and hydrogen as that which, I conceive, is burning on the surface of the luminous cone, and which *there*, above the point of the latter, produces the maximum temperature.

Unfortunately, a direct solution of the question by an investigation of the gases contained in the luminous envelop, is exceedingly difficult. Much remains to be done in the study of the details of the differentially variable processes by which the familiar phenomenon of a luminous flame is produced; but what *is* known is at least worthy of a place in the text-books.

ART. XVII.—*A Notice of some Manuscripts in Central American Languages;* by DANIEL G. BRINTON, A.M., M.D.

THE natives of Yucatan and most of those who formerly inhabited the provinces of Vera Paz, Chiapas, Guatemala, and Tabasco, spoke closely related languages, the most prominent of which was the Maya, current on the peninsula. Its name has been applied generically to them all, and may thus be understood to include the Maya proper or Yucateca, the Cakchiquel or Guatemalteca, the Quiche or Utlateca, the Tzutuhil or Atiteca, the Zahlopakap, the Pokome, the Tzotzil, the Mam, the Tzendal supposed to be, or most nearly to resemble, the parent stem, and the Huasteca of Tamaulipas which was

shown by the authors of the *Mithridates** to be an offshoot of the Maya. These various dialects resemble each other, both in vocabularies and grammatical forms as closely as the various Romanic tongues of modern Europe.

This linguistic family is of great interest for several reasons. It included the most highly civilized portions of the red race; their ruined cities are among the wonders of the New World; they had elaborated a phonetic alphabet far superior to the picture writing of the Aztecs; they had a body of mythology and poetry of which some very respectable relics still exist; and what of civilization was found in ancient Anahuac is supposed by many to have been inspired by them; moreover there is some philological ground to believe that the Natchez of Louisiana, the most cultivated aboriginal nation north of Mexico, had a large infusion of their blood.

They have deservedly therefore attracted the especial attention of those given to the study of native American languages. Mr. E. G. Squier has published a "Monograph of authors who have written on the languages of Central America, and collected vocabularies or composed works in the native dialects of that country" (New York, 1861); the Abbé E. C. Brasseur de Bourbourg has emphasized their importance and in his "*Collection de documents dans les langues indigènes*" (Paris, 1862–64,) has laid before the world that most interesting Quiche document, the Popol Vuh; Count Francisco Pimentel has treated of them at considerable length in his work on the languages of Mexico; M. H. de Charencey of Caen has inserted several excellent essays upon them in various scientific serials; while Dr. H. Berendt of Tabasco has collected a vast amount of material in the different dialects, which he expects to send to press on his return from the explorations in Central America in which he is now engaged.

In addition to the materials here indicated for a comparative study of this group there are in the library of the American Philosophical Society at Philadelphia, some manuscripts presented by Mariano Galvez, Governor of Guatemala, in 1836. They seem to have escaped the notice of scholars, their very existence there having been entirely unknown even to Mr. Squier, of New York City, although he tells us in the introduction to the above mentioned monograph that he had "given ten years of devotion to Central American subjects;" while not one of them is included in the more recent list of works given by Pimentel,† nor in Ludewig's "Literature of

* *Mithridates oder Allgemeine Sprachenkunde*, Th. III, Abth. III, S. 15, Berlin, 1813.

† *Cuadro Descriptivo de las Lenguas Indigenas de Mexico*, Tom. II, p. 124, Mexico, 1865.

American Aboriginal Languages." Some notice of them therefore will doubtless be welcome to "Americanistes."

The first I shall describe is a work on the Cholti dialect of the Maya by Francisco Moran. It is a small quarto of 92 leaves. The first three pages contain a narrative in Spanish, difficult to decipher, by Thomas Murillo, a layman, touching the missions in 1689–92. Then comes one leaf not numbered, with notes on the verso in Cholti, nearly illegible. On the recto of the fourth leaf,—

Arte ‖ en lengua cholti que qui ‖ ere decir lengua de mil ‖ peros.

32 pages in a clear hand, ornamented with scroll work and pen sketches of birds and grotesque animals. On page 35,—

Libro de lengua cholti que quiere ‖ decir lengua de milperos.

24 pages in a cramped but legible hand. At the end the colophon,—

Fin del arte q^{e} trae no. M. R.^{do} P.^{e} Frai Fran^{co} moran en un libro de quartilla grande alto, que enquaderno i Recogio de nuestros Religiosos i barias cosas [añadió], el R.^{do} P.^{e} Frai Alonzo de Triana; Requiescant in pace todos. Amen Jesus, Maria Joseph.

A few notes on elegant phrases are added "que mi dio el P. Angel."

This is a duplicate of the preceding *Arte*, differing from it, however, in several particulars, being more full and accurate. They both seem to be copies of the original of Moran, not the one of the other.

After the *Libro* follow eight leaves of questions and answers at the confessional, etc., in Cholti. On p. 77 commences,—

Confessionario en lengua ‖ cholti, escrito en el pue ‖ blo de san lucar salac de ‖ el chol, año de 1685:

three leaves ending with a catchword indicating that it is but a fragment.

The remaining leaves are occupied by a vocabulary, Spanish and Cholti, chiefly on the rectos only. At the commencement is the following marginal note,—

Todo el Vocabulario grande de no. M. R. P.^{e} fr. fran^{co} moran esta tra Dusido en este libro, Por el ABesedario, i algunos bocablos mas.

The colophon is,—

En este pueblo de lacandones llamado de Nta Señora de los dolores en 24 de Junio dia de S.^{n} Juan de 1695 años.

We have here therefore two copies of the grammar and one

of the vocabulary of the Dominican missionary Francisco Moran, referred to by Father Francisco Vasquez in his *Cronica* (1714) as written in the characters invented by the Franciscan friar Francisco de la Parra (about 1550) to express the five peculiar consonants of the Maya group of languages. These are modifications of *k*, *p*, *ch*, *t*, and *tz*.* Both these copyists have, however, adopted Roman letters. Neither the original nor any other copies are known to exist, nor any other work in the Cholti dialect, though a certain Father Córdoba also wrote a grammar of it.† It has even been uncertain whether the Cholti was an independent dialect. It is not mentioned at all in Ludewig's "Literature of American Aboriginal languages," and Mr. Squier gives the title of Moran's work from Vasquez thus,—

"Arte de la Lengua Cholti (Chorti ?)."‡

The Chorti, however, was spoken in Chiquimula and vicinity, while the Cholti, Chol, or Putum, was the dialect of the village of Belen in Vera Paz, of parts of Chiapas, and generally of the eastern Lacandones among the mountains between the former province and Guatemala. The name *chol* means cornfield, in Mexican Spanish *milpa*, and *ahcholob* or *cholti* owners or cultivators of cornfields, *milperos*. From the short vocabulary of Chorti collected by Mr. Stevens at Zacapa it appears to be farther than the Cholti from pure Maya.

The grammar of Moran is succinct, clear, and comprehensive, and eminently deserves publication, together with selections from the vocabulary. I have made a careful copy of it for my own use and have found it of great service as illustrating certain points of growth in these idioms, for instance with reference to the development of the personal pronouns, recently discussed in a scholarly essay by M. de Charencey;§ and affording some additional illustration of the "vowel echo," *l'echo vocalique* of the Maya dialects, to which the same writer has called attention as analogous to the law of the harmonic sequence of vowels common in Scythian languages.‖

The remaining manuscripts are in the Cakchiquel dialect, at one time and even yet much spoken and studied in Guatemala, and hence called Guatemalteca.

* I have also noticed the occasional use in these manuscripts of a peculiar vowel sound represented by an *i* with a diacritical mark beneath it.

† Pimentel. *Cuadro Descriptivo de las Lenguas Indígenas de Méxco*, T. II, p. 234. Córdoba is not mentioned by Mr. Squier.

‡ *Monograph of Authors*, etc., p. 38.

§ *Le pronom personnel dans les idiomes de la famille Tapachulane-Huastèque*: Caen, 1868.

‖ *Etude comparative sur les langues de la famille Maya-Quiché*, *Revue Américaine*, Tom. I.

Calepino ‖ en lengua cakchi ‖ quel por Fray Francis ‖ co de Varea hijo de ‖ esta S. Provincia del ‖ SS. nombre de Jesvs ‖ de Religiosos de ‖ N. P. S. Francisco de Goatema ‖ la.

A small 4to, one unnumbered leaf, 227 leaves paged, 11 unnumbered leaves of additions. Colophon at foot of page 453,—

Acabase de escrevir y trasladar este bocabulario yo fray franco ceron, siendo guardian aunque sine meritis deste convento de S. Pedro de la laguna, oy dia catorse de enero del año del Señor de mil seyscientos y noventa y nuebe, dia del Dulcissimo nombre de Jesus Patron de nuestra S. Provª de Gua.ttª y en el tercer año del Provincialato de N. M. R. P. fr. Juan Bautista.

The title is on the recto of the second leaf. On the recto of the first leaf is the form of absolution in Latin and Cakchiquel; on the verso a note dated 1732 to the effect that the owner, a priest, received this volume in payment for masses for the soul of its previous possessor, a certain Señor Achutegui.

The dictionary is Cakchiquel and Spanish, written closely but legibly, with 35 lines to a page and averaging about four lines of examples to each word. An abundance of phrases and forms are given, but the alphabetical order is not strictly preserved. The characters of Parra are used throughout.

No author of the name of Varea is mentioned by Mr. Squier. But Francisco *Varela* is said to have gone to Guatemala in 1596 and to have composed a "Calepino" in 400 pages folio.* No doubt this is the same person, and unless the original still exists in the convent of San Francisco de Guatemala, this is probably the only monument of his labor extant.

The next manuscript is a large folio, bound like the preceding in parchment, of 476 leaves numbered on the recto. The title is,—

Vocabulario ‖ De la Lengua cakchiquel, v, Guatimalteca ‖ Nueuamente hecho y recopilado con summo estudio ‖ trauajo y erudicion por el P.e F. Thomas Coto. Pre ‖ dicador y Padre de esta Prouj.ª de el S.S.mo Nõbre ‖ de Jesus de Gùatimala. En que se contienen ‖ todos los modos y frases elegantes conque los ‖ Naturales la hablan y d. q. se pueden valer ‖ los Ministros estudiossos para su mejor ‖ educacion y enseñanza.

This dictionary is a splendid testimonial to the zeal and scholarship of the Franciscan missionaries. The pages are large, with double columns, 37 lines to a page, written quite distinctly though here and there the ink has faded so that it is difficult to read. The first 15 pages are handsomely written

* Monograph, etc., p. 47.

in imitation of printed letters. The characters of Parra are adopted for the five peculiar sounds. Unfortunately the copy is incomplete, ending with the word *vendible.* As it is exclusively Spanish and Cakchiquel, it complements the Cakchiquel and Spanish *Calepino* of Varea.

It should be observed that the letter C is wrongly bound so that the latter part of it comes first, and several other letters do not seem to have been finished. This copy appears to date from early in the last century and is unique so far as I know. Coto was a native of Guatemala and lived in the latter part of the 17th century. Mr. Squier gives under his name only one title; "Thesaurus Verborum; ó Frases y Elegancias de la Lengua de Guatemala;" which probably is the same work as the above. It is peculiarly valuable not only for the linguistic material it contains, but for the light it throws on numerous customs of the natives, on the botany and zoology of the country, and for its quotations of manuscript works in Cakchiquel. Coto's principal authorities are Father Francisco Maldonado's sermons in that tongue, those of Father Antonio Saz (*de san Joachim, de la visitacion, de la asuncion, de la concepcion, manual en la lengua* and others, none of them mentioned by Mr. Squier or Pimentel,) Father Domingo Vico, bishop of Chiapas, and the "*calepino*" of Varea.

Under many words quite a description is given of this or that usage. For instance, under the word *baile*, native dance, which I choose having in mind the remarks on it made by the Abbé Brasseur de Bourbourg in his introduction to the Quiche drama of Rabinal Achi,* he remarks that they are of many kinds; that for instance which represents Noah coming out of the ark is called *avatal*; that in which they whirl a stick with their feet, *vugh*; that only engaged in by lovers *xgul*; that in which they played on their flutes of hollow reeds, *lotz tun*; this latter, he adds, was prohibited by Bishop Uguarte on the representations of Antonio Prieto de Villegas, commissary of the holy office, a learned man, thoroughly versed in Quiché, and for twenty years incumbent of the benefice of Matzatenango; it was also prohibited by the diocesan constitution in 1690; several other *bailes* are also described.

Under the word *luna* he mentions that these Central American nations partook of a singular belief which we find very widely spread on the American continent. It was that an eclipse was caused by some animal eating the moon, and to drive it away accordingly they broke their jars, shouted, whipped their dogs, and made all the noise possible. They likewise attributed to this orb a malignant influence and supposed

* *Collection de Documents dans les Langues Indigénes*, vol. II.

her to be the cause of disease, a belief extremely common among the illiterate everywhere.

The fourth manuscript is a large folio of 77 leaves not numbered, written in Cakchiquel in ordinary characters. On the recto of the second leaf is the following title,—

Arte pronunciacion y ortographia de la lengua en el mismo ydioma ‖ Cakchiquel.

On the fourth line of the verso of the same leaf,—

Ramillete, Manual para los Yndios sobre ‖ la Doctrina Christiana ‖ por fray francisco Maldonado minorita, ‖ Sub Censura sante Romane eclesie Dialogo primo.

This "nosegay" or anthology consists of twelve dialogues on the confession, creed, sacraments, good works, etc., between a priest and his catechumen. After the twelfth dialogue there is an addition of nine leaves in Cakchiquel with the following title,—

Esta explica ‖ cion de la Doctrina Christiana ‖ va con el mesmo testo de la cartilla inpresa el Año ‖ de mill y quinientas y çinquenta y seys por explicar los ‖ terminos que los Yndios Saben mal entendidos, por tuvien ‖ do el mismo authorre fformado la dicha Cartilla por man ‖ dado de ill.mo Señor Don fray juan çapata y Sanctoval ‖ obispo de guatemala, se puso aqui en la misma forma ‖ que la Conrregie para que sirva de brevi.ssa exposicion A ‖ la antigua sub cenSura Sanct ‖ te Romane eccle ‖ ssie.

At the close is a table of contents followed by this colophon in Cakchiquel:

Chupam 6 de Julio huna 1748 año mixgizvi vugibaxic vae vutz libro Ramillete Manual tihobal quichin Yndios chupam vutzilz Dios Doctrina Christiana yn Seuastian lopez tzarin vae ueva voch-Sancta Maria Asumpçion tecpanatitan de tzolala.

Then follow two leaves in Cakchiquel headed:

A la emperatrix a la vergen Maria Señora Nra su humilde esclavo.

From this evidence we learn that this is a copy made in 1748 by Sebastian Lopez at Solola on Lake Atitan of two works, the older printed in 1556, author not given, the other by Francisco Maldonado. The former must be the "Doctrina Cristiana en Lengua Utlateca" or Quiche, published at Mexico in that year, whose author, Fray Francisco Marroquin died in 1563. It is true that this was said to be in Quiche,* and that Zapata y Sandoval was not a bishop until 1613.† But as I have

* Fr. Pedro de Betanzos who died in 1570, published a "Doctrina en Lengua de Guatemala" also at Mexico, year unknown. If this should prove to have appeared in 1563 also, one of the difficulties would be surmounted.

† Squier, Monograph, p. 52.

never seen a copy of Marroquin's *Doctrina*, I am unable to reconcile these discrepancies.

The *Dialoyos* is a work hitherto unknown of Maldonado, one of the most learned of the Franciscan missionaries. He lived in the latter half of the 17th century. The only one of his productions given by Mr. Squier is "Sermones y Panegiricos en Lengua Cakchiquelche," which is that also chiefly referred to by Father Coto in his dictionary.

The next work is a small quarto of 109 leaves. Unfortunately the first leaf, with the general title, is missing. The top of the second leaf commences in the midst of a sentence in a *Doctrina Christiana* in Cakchiquel. This covers ten leaves, and is followed by two leaves of "Preguntas de la Doctrina," all in Cakchiquel. Next comes a "Confessionario breve en lengua Cakchiquel." The Spanish translation of each question and answer is also given.

After the Confessionario are three leaves, unnumbered and blank, except that on the recto of the second is a Latin Prayer to the Virgin, difficult to decipher.

On the recto of the next leaf is the following,—

Arte ‖ de la lengua cak ‖ chiquel.

It is written in a clear small hand, covers fifty-four pages with 30 lines on an average to the page, sometimes with one column, sometimes with two, and closes with this colophon,—

Martes ã 24 de Junio de 1692 años dia del Nacimiento de S. Juan Baptista se acavo el traslado de oraçiones y Arte en Kakchiquel.

From the close of this to the 96th leaf there is another series of doctrinal questions headed,—

Vae *K*utubal *K*habal ti ‖ *K*ut ubex richin Christianos ‖ cakchiquel *K*habal ri ‖ chin cakchiquel vinak.

(I designate the peculiar modification of the consonants by italics.)

Another "Confessionario breve en lengua castellana y cakchiquel" then follows, twelve pages in length, differing considerably from the previous one. The rest of the volume is taken up with "Platicas," short discourses on religious subjects. One of them is an incident from the life of Saint Vincent Ferrer, related for the purpose of "terrifying the natives, and dispelling the shame they usually have about confessing." There is an index to the book, and on the verso of the last leaf this note in regard to the binding,—"Este quaderno es de Fr. Alberto Miguez;" said "quaderno" being in dark calf, without boards, and with strings. The characters of Parra are

employed in all the divisions of the work, and the writing is mostly quite legible.

There is no hint throughout where this was written, nor by whom. The colophon above quoted seems to show that it is the original, at least of the *Arte* and the prayers. From the mention of Saint Vincent Ferrer, a Dominican, and from the known rivalry of the two orders at that time in Central America, I am inclined to attribute it to a Dominican rather than a Franciscan. None of the bibliographical authorities already quoted mention any writer of either order who prepared works of this kind in Cakchiquel at or very near 1692. The manuscript proceedings of the Philosophical Society for Sept. 1836, when the books were received, throw no light on the matter.

The linguistic value of the *Arte* is considerable. Only two grammatical notices of the language seem to have been published, one about 1560 in Mexico, another in 1753, in Guatemala. Both of them are excessively rare, and indeed it is doubtful if any copy of the first is in existence. The Cakchiquel is peculiarly important in the comparative study of this group of languages, and with the rich materials here at hand to illustrate all its constructions, a publication of this short manuscript with notes would be most welcome to American linguists.

In concluding this brief notice of these interesting documents I wish to express my acknowledgments to Prof. J. P. Lesley, librarian, and Mr. Eli K. Price, member of the Philosophical Society, for facilities afforded me in examining its library.

Art. XVIII.—*Notices of New Meteoric Irons in the United States;* by Charles Upham Shepard.

1. *Meteoric Iron from Auburn, Macon county, Alabama.*

In October last, Prof. J. Darby, of the East Alabama College, forwarded to me by mail at Amherst, about twenty grains of what he suspected to be meteoric iron, with the desire that I would subject it to examination. He stated in his letter that the fragments had been detached from a mass weighing about eight pounds that had been ploughed up in his neighborhood many years since, but which until lately had been overlooked in his collection. He described the mass as consisting of agglutinated irregularly shaped concretions, presenting the appearance of having from a previous state of separation, been suddenly compressed together into a single rounded mass.

A partial examination induced me to believe the fragments sent to be of meteoric origin; and led to a correspondence with Prof. Darby, which resulted in his placing one half the mass, weighing four pounds, at my disposal, accompanied with the following more complete history of the discovery:

"The man who brought the mass to me (and who was its discoverer) had taken it, without my knowledge, to a blacksmith's shop, where in the cold state it was broken in two upon an anvil, by means of a sledge hammer. Originally, it must have been nearly globular in form. The surfaces produced by the separation had, when I received the specimen, a metallic luster. The finder made known to me the exact spot where he had ploughed it up. It was on what is known as the Daniel plantation, about three-quarters of a mile west of our college building, and near the eastern edge of a field, just across a branch (small stream). I have searched in the region for other specimens without effect, but have instructed the negroes to bring to me any thing unusual they may hereafter discover. The name of the man who found the mass and his present residence are unknown."

On receiving the half of the mass I was at once struck with Prof. Darby's first description of its appearance. The surface of fracture, or separation, is coarsely granular, exhibiting large irregularly shaped concretions, which show only obscurely, traces of octahedral cleavage. The former metallic luster is now replaced by a rusty brown film; while numerous cracks or chinks are observable, not merely separating the concretions but often traversing the mass of each individual. Indeed the entire specimen is thus cracked up and subdivided by these open veins, as if it had been shattered by striking when in a semi-fused state, against a rock, at the time of its fall. So imperfect is the cohesion at present that it would not be very difficult to break it into pieces, (from the size of a large pea up to that of an almond) by vigorous blows from a sledge-hammer. Some of these concretions are partially stalactitic, tuberose or sub-mammillary, as if a secondary softening or fusion of the iron had taken place at the time of its descent. This structure is altogether peculiar for a meteoric iron, though not unknown in native copper and silver.

The larger concretions have a slight tendency to separate into smaller ones of the size of peas, whose figure, however, is that of the granular individuals of magnetite and pyrites, except perhaps in having a tendency to an elongation in the concretion which occasionally passes into the sub-columnar structure.

One single globule of troilite (sulphid of iron), half an inch in diameter is visible upon the fractured surface of the mass. It is compact in structure, and yellowish-brown in color.

As yet I have not been able to have any portion of the mass regularly slit and polished ; but a surface of one of the larger compound concretions, on being ground upon its broader side and polished, afforded me an area of half an inch square. This face, on being subjected to the action of dilute nitric acid, gave me a series of markings altogether new. They are extremely fine and delicate in their dimensions, and require a strong light with the aid of a microscope, to be seen with distinctness. The first character that displays itself is somewhat that of a mesh or net-work, and arises from the polygonal boundaries of the granular concretions. The areas within these lines or edges (which are exceedingly thin) have a glittering luster when held at a fixed angle to the light, though this angle often varies for different concretions, as in the case of a polished surface of coarse grained calcite or fluor. The second character that arrests attention in the examination, is the finely striated surface of each concretion,—one set of lines being perfectly straight and equidistant, as in calcite and labradorite, while a second set, but less distinct, cross these at right angles. The final peculiarity of the markings consists in this,—that these fine striæ are wholly made up of dots or beads, which are arranged in almost absolute contact, and are therefore to be regarded as consisting wholly of sections of rhabdite needles, while on the other hand, the mesh-like markings first noticed, are composed of plates of schreibersite.

From the foregoing it is apparent that the Auburn iron, when etched, is unlike any other hitherto described. But before a complete account can be given of its internal structure, an opportunity must be had of making further observations upon slices properly prepared from different portions of the mass.

The specific gravity, as obtained from four fragments, varied from 7·0—7·17, and gave 7·05 as the mean.

The iron is apparently free from chlorine. It dissolves in hydrochloric acid without extrication of sulphuretted hydrogen ; and leaves behind a slight residue of thin brilliant, blackish scales and needles. The following result was obtained on about two grams weight of the iron :

Iron,		94·580
Nickel,		3·015
Phosphorus,		0·129
Insoluble,		0·523
Chromium, Magnesium, Calcium, Silicon, (?)	and loss	1·753
		100·000

Inasmuch as the iron analyzed was slightly enfilmed with oxyds, that, in the results obtained, had to be calculated back to the metallic state in common with the oxyds coming from the pure metals, a trifling part of the loss in the analysis should go to increase the iron and nickel above given.

The composition of the troilite, schreibersite and rhabdite in the mass is too well known to render necessary any attempt to analyze them in the present case. Neither cobalt, tin, nor copper was detected in this iron.

2. *Meteoric Iron from Southeastern Missouri.*

For my knowledge of this iron I am indebted to Prof. B. F. Shumard, of Saint Louis, who sent me a specimen of it several years ago, but through an accident it failed to reach me until lately. He wrote me under date of Nov. 4, 1868, as follows: "The specimen is from one in the collection of the St. Louis Academy of Sciences which I found among minerals that belonged to the old Western Academy of Sciences, of St. Louis. The label with it gives only '*S. E. Missouri*' as the locality. Its meteoric character was not known until I examined it."

In reply to my request for further information, Prof. Shumard has favored me (Dec. 18) with the following additional particulars: "The specimen in the Academy's collection is irregularly lozenge-shaped, $3\frac{3}{16}$ inches long, $1\frac{1}{2}$ wide, and $1\frac{1}{16}$ thick. The extremities and upper face are rough and irregular, one lateral piece is smooth with a wavy surface, the other has been cut to supply specimens to Prof. Silliman, Haidinger and yourself. The under side is rough near one end, while the remainder of it has been smoothed by hammering. The specimen bears the appearance of having been heated. Its present weight is nine ounces; and if you will add to this what has been taken to furnish the specimens referred to above you will probably not be far from the truth, in calling the original weight twelve ounces. Nothing has been published concerning the specimen. I discovered it in the museum of the Academy during the year 1863."

In respect to the figures developed by etching, it belongs to my order of megagrammic irons; and most resembles those of Arva and Cocke county. It is rich in schreibersite, insomuch that when long acted upon by acid, this mineral projects in thick laminæ above the surface, resembling mica on certain weathered coarse grained granites. The bars and spaces which are intermediate, however, are not traversed by those delicate lines of the same substance, so generally occurring in other irons.

Specific gravity 7·015—7·112. It appears to contain no chlorine. It gave:

Iron,	92·096
Nickel,	2·604
Schreibersite,	5·000
Chromium, cobalt, magnesium, phosphorus,	traces.

A fine residue of Fe Si and C. Neither copper nor tin was found.

3. *Composition of Meteoric Iron from Losttown, Cherokee Co., Georgia.*

My general description of this iron was contained in vol. xlvi, p. 257 of this Journal. Its analysis has afforded me—

Iron,	95·759
Nickel,	3.660
Insoluble (schreibersite and rhabdite,)	0·580
Chromium, cobalt, tin (?), magnesium,	traces.

Charleston, S. C. Dec. 29, 1868.

Art. XIX.—*On Nitrification;** by S. W. Johnson.

Formation of nitrogen compounds in combustion.—Saussure first observed (Ann. de Chimie, lxxi, 282), that in the burning of a mixture of oxygen and hydrogen gases in the air, the resulting water contains ammonia. He had previously noticed that nitric acid and nitrous acid are formed in the same process.

Kolbe (Ann. Chem. u. Pharm., cxix, 176) found that when a jet of burning hydrogen was passed into the neck of an open bottle containing oxygen, reddish-yellow vapors of nitrous acid or nitric peroxyd, were copiously produced on atmospheric air becoming mingled with the burning gases.

Bence Jones (Phil. Trans., 1851, ii, 399), discovered nitric (nitrous ?) acid in the water resulting from the burning of alcohol, hydrogen, coal, wax, and purified coal-gas.

By the use of the iodid of potassium starch-test (Price's test), Boettger (Jour. für Prakt. Chem., lxxxv, 396,) and Schönbein (ibid., lxxxiv, 215,) have more recently confirmed the result of Jones, but because they could detect neither free acid nor free alkali by the ordinary test-papers, they concluded that nitrous acid and ammonia are simultaneously formed—that, in fact, *nitrite of ammonia* is generated in all cases of rapid combustion.†

* The substance of this paper was orally presented to the National Academy of Sciences, in August, 1868.

† Nitrous acid does not appear when the combustible contains sulphur, since it is decomposed at high temperatures by sulphurous acid.

Meissner (Untersuchungen über den Sauerstoff, 1863, p. 283,) was unable to satisfy himself that either nitrous acid or ammonia is generated in combustion.

Finally, Zabelin (Ann. Chem. u. Ph., cxxx, 54), in a series of careful experiments, found that when alcohol, illuminating gas and hydrogen burn in the air, nitrous acid and ammonia are very frequently, but not always formed. When the combustion is so perfect that the resulting water is colorless and pure, only nitrous acid is formed; when, on the other hand, a trace of organic matters escapes oxydation, less or no nitrous acid, but in its place ammonia appears in the water, and this under circumstances that preclude its absorption from the atmosphere.

Zabelin gives no proof that the combustibles he employed were absolutely free from compounds of nitrogen, but otherwise, his experiments are not open to criticism.

Meissner's observations were indeed made under somewhat different conditions; but his negative results were not improbably arrived at simply because he employed a much less delicate test for nitrous acid than was used by Schönbein, Boettger, Jones and Zabelin.*

We must conclude then, that nitrous acid and ammonia are usually formed from atmospheric nitrogen during rapid combustion of hydrogen and compounds of hydrogen and carbon. The quantity of these bodies thus generated is, however, in general so extremely small as to require the most sensitive reagents for their detection.

Formation of nitrogen compounds at low temperatures.—Schönbein was the first to observe that nitric acid may be formed at moderately elevated or even ordinary temperatures. As is well known he obtained several grams of nitrate of potash by adding carbonate of potash to the liquid resulting from the slow oxydation of phosphorus in the preparation of ozone.

More recently he believed to have discovered that nitrogen compounds are formed by the simple evaporation of water. He heated a vessel (which was indifferently of glass, porcelain, silver, &c.), so that water would evaporate rapidly from its surface. The purest water was then dropped into the warm dish in small quantities at a time, each portion being allowed

* Meissner rejected Price's test in the belief that it cannot serve to distinguish nitrous acid from hydric peroxyd. He therefore made the liquid to be examined alkaline with a slight excess of potash, concentrated to small bulk and tested with dilute sulphuric acid and ferrous sulphate, (Unters. ü. d. Sauerstoff, p. 233). Schönbein had found that iodid of potassium is decomposed after a little time by *concentrated* solutions of hydric peroxyd, but is unaffected by this body when dilute, (Jour. für prakt. Chem. lxxxvi, p. 90.) Zabelin agrees with Schönbein that Price's test is decisive between hydric peroxyd and nitrous acid. (Ann. Chem. u. Ph., cxxx, p. 58.

to evaporate away before the next was added. Over the vapor thus generated was held the mouth of a cold bottle until a portion of the vapor was condensed in the latter.

The water thus collected gave the reactions for nitrous acid and ammonia, sometimes quite intensely, again faintly, and sometimes not at all.

By simply exposing a piece of filter paper for a sufficient time to the vapors arising from pure water heated to boiling and pouring a few drops of acidified iodid of potassium-starch-paste upon it, the reaction of nitrous acid was obtained. When paper which had been impregnated with dilute solution of pure potash was hung in the vapors that arose from water heated in an open dish to 100° F. it shortly acquired so much nitrite of potash as to react with the above named test.

Lastly, nitrous acid and ammonia appeared when a sheet of filter paper, or a piece of linen cloth, which had been moistened with the purest water, was allowed to dry at ordinary temperatures, in the open air or in a closed vessel. (Jour. für Prakt. Chem., lxvi, 131). These experiments of Schönbein are open to criticism and do not furnish perfectly satisfactory evidence that nitrous acid and ammonia are generated under the circumstances mentioned. Bohlig has objected that these bodies might be gathered from the atmosphere where they certainly exist, though in extremely minute quantity.

Zabelin, in the paper before referred to (Ann. Ch. Ph., cxxx, p. 76), communicates some experimental results which, in the writer's opinion, serve to clear up the matter satisfactorily.

Zabelin ascertained in the first place that the atmospheric air contained too little ammonia to influence Nessler's test, which is of extreme delicacy and which he constantly employed in his investigations.

Zabelin operated in closed vessels. The apparatus he used consisted of two glass flasks, a larger and a smaller one, which were closed by corks and fitted with glass tubes, so that a stream of air entering the larger vessel should bubble through water covering its bottom and thence passing into the smaller flask should stream through Nessler's test. Nextly, he found that no ammonia and (by Price's test) but doubtful traces of nitrous acid could be detected in the purest water when distilled alone in this apparatus.

Zabelin likewise showed that cellulose (clippings of filter paper or shreds of linen) yielded no ammonia to Nessler's test when heated in a current of air at temperatures of 120° to 160° F.

Lastly, he found that when cellulose and pure water together

were exposed to a current of air at the temperatures just named, ammonia was at once indicated by Nessler's test. Nitrous acid, however, could be detected, if at all, in the minutest traces only.

The reader should observe that Boettger and Schönbein, finding in the first instance by the exceedingly sensitive test with KI and starch-paste, that nitrous acid was formed, when hydrogen burned in the air, while the water thus generated was neutral in its reaction with the *vastly less sensitive* litmus test-paper, concluded that the nitrous acid was united with some base in the form of a neutral salt. Afterward, the detection of ammonia appeared to demonstrate the formation of nitrite of ammonia. Schönbein's explanation of the mode in which this salt may be generated, viz., by the direct union of water and nitrogen, seems to have perfectly satisfied the chemical critics.*

This theory has, however, nothing to warrant it, even in the way of probability. If traces of nitrite of ammonia can be produced by the immediate combination of these exceptionally abundant and universally diffused bodies at common temperatures, or at the boiling point of water, or lastly in close proximity to the flames of burning gases, then it is simply inconceivable that a good share of the atmosphere should not speedily dissolve in the ocean, for the conditions of Schönbein's experiments prevail at all times and at all places so far as these substances are concerned.

The discovery of Zabelin that ammonia and nitrous acid do not always appear in equivalent quantities or even simultaneously, in no wise conflicts with any of Schönbein's facts. A quantity of free nitrous acid that admits of recognition by help of Price's test would not necessarily have any effect on litmus or other test for free acids. There remains then no necessity of assuming the generation of nitrite of ammonia, and the fact of the separate appearance of the elements of this salt demands another explanation.

The writer is not able perhaps to offer a fully satisfactory explanation of the facts above adduced. He submits, however, some speculations which appear to him entirely warranted by the present aspects of the case, in the hope that some one with the time at command for experimental study, will establish or disprove them by suitable investigations.

He believes that in no case can free nitrogen unite directly

* Zabelin was inclined to believe that his failure to detect nitrous acid in some of his experiments where organic matters intervened, was due to a power possessed by these organic matters to mask or impair the delicacy of Price's test, as first noticed by Pettenkofer and since demonstrated by Schönbein in case of urine.

with water, but in the conditions of all the foregoing experiments, it enters combination by the action of *ozone*, as Schönbein formerly maintained and was the first to suggest. Ozone is formed not only in all rapid combustions but also in the slow oxydation of organic matters (paper and linen.)

Pincus has lately published some observations which any chemist may readily verify, that demonstrate the formation of ozone in combustion at high temperatures. It is only necessary to hold a cold, clean and dry beaker glass for a few seconds over a jet of pure hydrogen burning from a metal tube with a flame $\frac{1}{8}$ of an inch high, and then to smell of its contents. The ozone odor is most plainly perceived. The same result may be obtained from a small flame of alcohol or of a stearine candle.—(Die Landwirthschaftlichen Versuchs-stationen, ix, 473.)

The formation of ozone in all cases of slow oxydation at common temperatures is in analogy with its appearance during the eremacausis of phosphorus, and if antozone really exists and is the genetic complement of ozone as is indicated so strongly by the researches of Schönbein and Meissner, we must consider the case pretty well made out in theory, for hydric peroxyd which is held to be the result of the union of antozone with water, is formed in so many instances of slow oxydation of metals and organic bodies that Schönbein felt justified in assuming its production, or that of a corresponding organic antozonid in them all.—(Jour. für. prakt. Chem., xcviii and xcix.)

In Schönbein's experiments before mentioned, where paper or linen were not employed, the dust of the atmosphere probably supplied the organic matters.

The first result of the oxydation of nitrogen is nitrous acid alone (at least Schönbein and Bohlig detected no nitric acid), when the combustion is complete as in case of hydrogen, or when organic matters are excluded from the experiment. Nitric acid is a product of the subsequent oxydation of nitrous acid. When organic matters exist in the product of combustion, as when alcohol burns in a heated apparatus yielding water having a yellowish color, it is probable that nitrous acid is formed, but is afterward *reduced* to ammonia.

The reduction of nitrates to nitrites by various organic matters was announced by Schönbein several years ago. He found that all the vegetable and animal albuminoids, gelatine, and most of the carbohydrates, especially starch, glucose and milk-sugar (but not cane sugar) had this effect.—(Jour. für. prakt. Chem., lxxxiv, p. 207.) Zabelin in the article before cited, refers to Schönbein as authority for the fact that these organic

bodies reduce nitrites to *ammonia* and ultimately to nitrogen and although we have not been able to find such a statement in those of Schönbein's papers to which we have had access, it is entirely credible and in accordance with numerous analogies.

Pelouze could find no nitrates (nor nitrites?) in the drainings of dung-heaps. Lawes, Gilbert, and Pugh, detected no trace of nitrites in moist mixtures of ignited earth, with bean-meal, starch and saw-dust, over which ozone (&c., by phosphorus,) was passed daily for several months. (Trans. Roy. Soc., 1861, p. 496.) Boussingault states that mixing quick-lime or carbonate of potash with garden soil prevents nitrification and causes the development of ammonia. (Agronomie, etc., iii, p. 200.) In these cases the readily oxydable matters were in excess of active oxygen; the process was therefore a *putrefactive and reducing one*, and although nitrites may have been and doubtless were formed on the surface, where oxygen was in excess, they were deoxydized in the interior of the mass.

Zabelin alludes to this reduction of nitrites by organic bodies not with the purpose of accounting for the formation of ammonia from nitrous acid, but to explain why he failed to detect nitrous acid in some of his experiments. Apparently firm in the conviction that nitrite of ammonia was in all cases formed, he says, "I believe that at the high temperature of our experiments the nitrite of ammonia produced was decomposed into ammonia that was carried off and into nitrous acid which mostly remained in the water of the flask, where it was probably further decomposed, under oxydation of the linen or the paper. Therefore it was found only in traces while ammonia was very easy to identify." He says further, "By our experiments in the burning of illuminating gas and alcohol we have recognized the same action of organic matters on nitrites; nay, nitrous acid gradually decomposed in their presence at ordinary temperatures; the water at the same time acquired the power of decolorizing iodized starch." (Ann. Chem. Pharm., cxxx, 85.) Now ammonia speedily bleaches starch made blue by iodine, and thus Zabelin's observations sustain our hypothesis.

If, as thus appears extremely probable, ozone is developed in all cases of oxydation both rapid and slow, then every flame and fire, every decaying plant and animal, the organic matters that exhale from the skin and lungs of living animals or from the foliage and flowers of plants, especially, perhaps, the volatile oils of cone-bearing trees, are indirectly, means of converting a portion of free nitrogen into nitrous and nitric acids, or ammonia.

In the interesting experiment of Mr. Loew, where pure water evaporating from the surface of paper which has been impregnated with alloxan, gives rise to the formation of ammonia as is indicated by the red color of murexyd supervening, (this Journal, xlv, p. 29,) the explanation we have offered, accounts for the facts observed as well as the hypothesis of Schönbein. We assume eremacausis of the moist paper, perhaps of the alloxan itself, to take place, ozone and by it nitrous acid to be formed, the latter being subsequently reduced to ammonia.

Our explanation is further sustained by the facts which we possess concerning the part which the organic matters perform in nitrification as it goes on within the soil.

Organic matters are universally recognized as essential in the composts which are employed in saltpeter plantations. Those earths in which nitrification proceeds spontaneously, are in general, characterized by a considerable content of humus. We have precise observations by Boussingault which demonstrate that organic matters are indispensable to nitrification. This investigator in the prosecution of his researches on vegetable nutrition, found in a large series of experiments, that when plants vegetate in calcined earth, neither the plant nor the earth gathers appreciable quantities of nitrogen from the atmosphere, during a period of several months, but when soil containing humus is employed under similar circumstances, either the soil or the plant (in most cases both) assimilate nitrogen to a decided degree.

For example, a lupin vegetating for ninety-seven days in 130 grams of rich garden soil (mixed with pure sand to favor access of air) the whole being confined in a glass case, assimilated 0·0217 grm. of nitrogen, and the soil far from exhibiting loss, during the same period, fixed 0·0454 grm. of this element. (Agronomie, etc., t. 1, p. 339). Of the nitrogen thus gathered from the atmosphere and fixed in a solid form by the soil, only one-ninth existed in the state of nitric acid and ammonia, when the experiment was concluded. We infer that this nitrogen for the most became a constituent of the soil by nitrification induced by the eremacausis of its humus, with the formation of ozone.

The passage of nine-tenths of this fixed nitrogen into a constituent of humus, where it doubtless exists in what we may call organic combination, probably took place by reduction of nitrogen oxyds to ammonia, and subsequent union of the latter with products of the alteration of cellulose in the same way that amid-like bodies have been obtained by Dusart, Schützenberger and P. Thenard, in heating together ammonia with dextrin, starch and glucose, in partial realization of Prof.

T. S. Hunt's idea of the synthesis of gelatine, from a carbohydrate and ammonia.—(Kekulé's Lehrbuch, ii, 356.)

Certain experiments executed by Mulder, more than twenty years ago (Chemistry of Animal and Vegetable Physiology, p. 673,) confirm the view we have taken. Two of these were "made with beans which had germinated in an atmosphere void of ammonia, and grown in one case in ulmic acid prepared from sugar, and also free from ammonia; and, in the other case, in charcoal, both being moistened with distilled water, free from ammonia. The ulmic acid and the charcoal were severally mixed up with one per cent. of wood ashes, to supply the plants with ash-ingredients. I determined the proportion of nitrogen in three beans and also in the plants that were produced by three other beans. The results are as follows :—

	White beans in ulmic acid.		Brown beans in charcoal.	
	Weight.	Nitrogen.	Weight.	Nitrogen.
Beans,	1·465 grm.	50 cub. cent.	1·277	27 cub. cent.
Plants,	4·167 "	160 " "	1·772	54 " "

The white beans, therefore, whilst growing into plants in substances and an atmosphere, both of which were free of ammonia, had obtained more than thrice the quantity of nitrogen that originally existed in the beans ; in the brown beans the original quantity was doubled." Mulder believed this experiment to furnish evidence that ammonia is produced by the union of atmospheric nitrogen with hydrogen set free in the decay of organic matters. But the researches of Will have fairly established the impossibility of nascent hydrogen uniting to free nitrogen. The results of the experiments are fully explained by assuming that nitrogen was oxydized in nitrification and no other explanation yet proposed, accords with existing facts.

To sum up, the writer believes that in nature, free nitrogen enters into combination, in all cases, by oxydation, that the agent of oxydation is ozone, that in the soil this ozone originates, for the most part, in the slow oxydation of organic matters, and that ammonia and the organic nitrogen of humus, peat and coal are the result of the reduction of oxyds of nitrogen either in the living organism in the acts of nutrition, or by the organic matters of the dead plant or animal. The union of atmospheric nitrogen and oxygen under the influence of electrical tension has been shown by Meissner to be preceded by the production of ozone. By a long series of critically conducted observations, Daubeny (Jour. Chemical Soc., 1867,) has made probable that ozone appears in the vicinity of active foliage exposed to sunlight, and concludes that the oxygen set free from combination in the plant, is partly ozonized,

as is true of that which separates in the decomposition of permanganates and chromates by oil of vitriol.* The plant, then, appears to be an agent of nitrification when living as well as when dead, and ozone is the result of a molecular change which accompanies the decomposition as well as the formation of oxygen compounds.

Sheffield Laboratory, Dec., 1868.

ART. XX.—*Geological Notes on the Andes of Ecuador;* by JAMES ORTON.

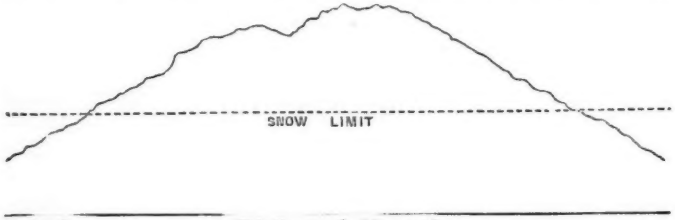
THE Andes traverse the Republic of Ecuador in two Cordilleras, which are nearly parallel to each other and on the average, forty miles apart. The great valley which they enclose is about 300 miles in length, and has a general direction of 58° W. It is divided by two transversal dikes—the knots of Tiupullo and Assuay into three basins; Quito, Ambato, and Cuenca, having the respective altitudes of 9,500, 8,000 and 7,800 feet above the Pacific. There are some subordinate knots, and some longitudinal ridges; but all the basins lie parallel to the axes of the Cordilleras—a characteristic feature of the Andes. There are deep valleys on the outside flanks, which are evidently valleys of erosion; but the basins enclosed by the Cordilleras were created with them.

We believe with Darwin, that the Andes did not suddenly reach their present gigantic proportions. Wilson counted six terraces in going up from the sea, through the province of Esmeraldas toward Quito. Moreover, such an assemblage of great volcanoes, among them Cotopaxi, the highest open vent on the earth's surface, and Sangai, the most active in its eruptions, shows that the energy which heaved the Andes, is of deep seated origin, and that it is not yet expended. We are also reminded of the law that "volcanoes in a state of action, concur with proofs of recent elevation." Above the terraces are the *cerros*, or outlying spurs; and still higher are the *paramos* or bleak, grassy highlands, out of which rise the icy peaks. The west slope of the Ecuadorian Andes, is about 275 feet per mile; on the east, it is 125.

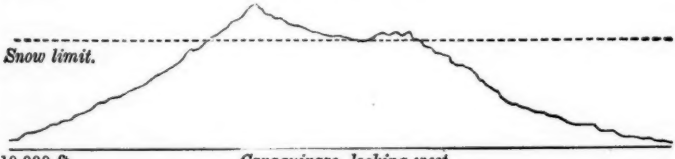
The mountain chain is built up of granitic, gneissoid and schistose rocks, often in vertical position, and capped with

* May not the liberation of chlorine in preparing oxygen from a mixture of chlorate of potash and oxyd of manganese, be due to the action of ozone? Chlorine appears when the decomposition is effected in a low heat, but not when a high temperature is used. In the latter case ozone cannot exist.

trachyte and porphyry. Large masses of *solid* rock are rarely seen; everything is cracked, calcined or triturated. While in Bolivia, the eastern Cordillera shows a succession of sharp, ragged peaks, in contrast with the conical summits of the Cordillera of the coast; there is no such distinction in the Andes of the equator. The eastern Cordillera, has a greater mean height, and it displays more volcanic activity. Twenty volcanic mountains surround the great valley, of which twelve are in the oriental chain. Three of the twenty (Cotopaxi, Sangai and Pichincha,) are now active; and five (Chiles, Imbabura, Guamani, Tunguragua and Quirotoa,) are known to have been active since the conquest. The truncated cone of Cotopaxi, the jagged, Alpine crest of ruined Caraguirazo, and



10,000 ft. *Chimborazo, looking west.*



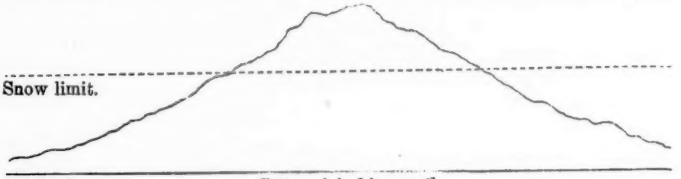
10,000 ft. *Caraguirazo, looking west.*

the dome of Chimborazo, are the representative forms of the volcanic summits. Antisana and Cayambi, are fashioned after Chimborazo, though the latter is table topped rather than convex; Altar, Quirotoa, Iliniza, Sincholagua, Rumiñagui and Corazon, resemble Caraguirazo; Tunguragua, Sangai, Llanganati, Cotocachi, Chiles and Imbabura, imitate Cotopaxi; Pichincha, Atacatzo and Guamani are irregular. The extinct volcanoes usually have double domes or peaks. This twin feature is prominent in other Andean volcanoes; e. g., Illimani.

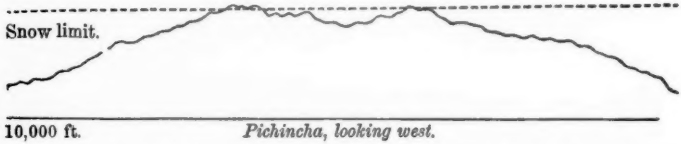
The growth of the cones since they began to erupt, is plainly exogenous. They rarely eject liquid lava, but chiefly water,* mud, ashes and fragments of trachyte and porphyry. From the deluges of water, result deep furrows in the sides;

* Much of the water sent down from Cotopaxi, may be due to the melting of snow; but this cannot be true of Pichincha or Imbabura.

and from the prevalence of the east wind, which is always met by the traveller on the crest of either Cordillera, there is a greater accumulation of ashes, and less snow on the west slope. In some of the craters, particularly of Pichincha, Altar and Rumiñagui, the western wall is lower than the eastern. Cotopaxi is exceptional, being lowest on the east side.* As there is no synchronism in the eruptions of Etna and Vesuvius, so there is no simultaneous activity of Cotopaxi and Pichincha. These volcanoes must have independent reservoirs, for Cotopaxi is 3,000 feet higher than Pichincha, and only



Cotopaxi, looking south.



Pichincha, looking west.

thirty miles distant. It is generally believed by the natives, that Cotopaxi and Tunguragua, are sympathetic. The volcanoes of Ecuador, (excepting Sangai,) belong to Scrope's third order; "that in which eruptive paroxysms of intense energy alternate with lengthened periods of complete external inertness,—phase of prolonged intermittences."

Taking Cotopaxi as the center of the system of Ecuadorian mountains, we may arrange the lower peaks, on concentric orbits. On the first are Ruminagui and Sincholagua, 10 miles distant; on the second, Iliniza, Corazon, Atacatzo and Antisana, 25 miles; on the third, Quirotoa, Pichincha and Guamani, 30 miles; on the fourth, Langanati, 40 miles; on the fifth, Tunguragua, Caraguirazo and Cayambi, 50 miles; on the sixth, Chimborazo, Imbabura, and Cotocachi, 60 miles; on the seventh, Altar, 65 miles; on the eighth, Sangai, 75 miles; on the ninth, Chiles and Assuay, 100 miles.

The chief dome of Chimborazo, presents from Guaranda a magnificent paraboloidal mass; while from a spot near Riobamba, the profile of the whole mountain has the figure of a lion in repose. One fourth of the entire altitude is perpetu-

* In the volcanoes of the Galapagos Islands, the south wall is lowest; while the Mexican craters, are lowest on the northeast.

ally covered with snow. "Chimborazo (said Humboldt,) is formed of one simultaneously uplifted mass of trachyte which has pierced, and reposes upon, secondary strata," and Daubeny adds that "the trachyte dome was raised, and then the volcanic fire was shifted to another quarter." But to us the upper third of the mountain appeared like a vast accumulation of volcanic matter ejected around and over a fissure in the upturned metamorphic rocks of the Cordillera. The rounded contour of the trachytic beds, as well as their porous texture, as Scrope contends, indicates their protrusion in an imperfect state of liquidity. We observed the following rocks on Chimborazo :*

Fine-grained trachyte, gray, brown and dark colored	(common.)
" " soft, reddish,	"
Coarse, porphyroid trachyte, gray,	"
Cellular trachyte, iron stained,	"
Compact trachyte, gray,	(rare.)
Fine-grained trachyte with seams of flint,	"
Obsidian,	"

In the College of Riobamba are specimens of brown trachyte in quite regular trihedral prisms.

The crown of Pichincha presents three groups of rocky peaks. The most westerly one, called Rucu-Pichincha, alone manifests activity. It is the only volcano in Ecuador which has not a true cone crater. Some violent eruption beyond the reach of history, or tradition, has formed an enormous funnel-shaped basin 2,500 feet deep, 1,500 feet in diameter at the bottom, and expanding upward to a width of more than half a mile.† The abyss is girt with a ragged wall of dark trachyte which rises on the inside, either vertically or at the angle of 50°. The outside of the cone (so-called) is inclined 30°, and like the inside is covered with fine volcanic debris, chiefly pumice. The height of the cone as compared with the whole height of the mountain is as 1 to 10; that of Vesuvius being 1 to 3, and Teneriffe, 1 to 22. Bouguer and LaCondamine in 1742, were the first to reach the brink of this crater; Visse and Moreno in 1844, were the first to enter it. The descent is extremely perilous, but the traveller is rewarded with one of the most imposing sights in nature.‡ The bot-

* Complete series of the Rocks mentioned in this paper, are preserved in the Cabinets of the University of Rochester, and of Ingham University, LeRoy, N. Y. They were kindly identified by Dr. T. Sterry Hunt, F.R.S., the distinguished mineralogist of the Canada Survey.

† Orizaba in Mexico, 2,000 feet higher than Pichincha, has a crater 6,000 feet wide, but only 500 feet deep. That of Kilauea is from 600 to 1,000 feet deep.

‡ The author made two attempts to reach the bottom of this crater, the second of which was successful, Oct. 22, 1867. We were two hours in descending, and three hours in our exit. Mr. Farrand, a photographer, was the only American who had preceded us.

tom of the crater is covered with huge blocks of porphyry and trachyte scattered about in wild confusion. West of the center rises the real cone of eruption, an irregular heap of stones about 250 feet high and containing numerous fumeroles. As Moreno rightly says, all the vents are situated in this little cone. The present products are sulphur and plumose alum lining the fissures, and aqueous vapor, with a small percentage of carbonic and sulphurous gases. The temperature of the vapor just within the fumerole we found to be 184°, water boiling beside it at 189°·2. The gigantic wall which girdles this fiery mount, is not only lower on the west side, but a deep cleft leads down into the wilds of Esmeraldas. A year ago the column of smoke did not rise above the top of the crater, but the volcano has lately been showing signs of activity such as it has not exhibited since the last grand eruption of 1660. On the 19th of March, 1868, detonations were audible at Quito, five miles distant in a straight line; and three days after there were more thunderings, with a great column of vapor visible from Chillo, twelve miles to the east. These phenomena were accompanied by an unusual fall of rain. On the 16th of August, occurred the great earthquake, since which event Pichincha has not made any extraordinary display.* The solid products of Pichincha since the Spanish invasion have been chiefly pumice and ashes. The roads leading to Quito cut through hills of pumice. On the plain of Iñaquito and in the valley of Esmeraldas are vast erratic blocks of trachyte, some containing twenty-five cubic yards, and having sharp angles, and in some cases a polished unstriated surface. M. Visse does not consider them to have been thrown out of Pichincha, as LaCondamine and tradition have judged. We dislike to disagree with this *habile observateur*. It is true, as he says, that they could not have come out of the present cone at a less angle than 45°, for they would have hit the sides of the high escarpment and rolled back again, while at a higher angle they would not have reached their present location. But they could be the fragments of the upper portion of the original trachytic cone blown into the air, at the great eruption which cleared out the enormous crater. The following rocks we observed within and around Pichincha:

Pumice, (lapilli,)	(common.)
Coarse-grained trachyte with augite crystals,	"
Granular trachyte, grayish,	"
Fine granular trachyte, reddish,†	"

* The natives ascribe the earthquake of 1859 to Pichincha.

† Used as building material in Quito.

Porous trachyte, with augite crystals,	(common.)
Porphyroid trachyte, dark base,	"
" " reddish,	"
" " gray,	"
Very compact trachyte, gray,	"
Sulphur, seen only in the crater, where it is abundant either pure or forming a conglomerate with cinders,	"
Fine grained trachyte, iron-stained,	(rare.)
Porous, granular trachyte, iron-stained,	"
Soft, friable trachyte, yellowish,	"
Fine-grained, decaying trachyte, with seams of flint,	"
Porphyroid trachyte, disintegrating,	"
Granular trachyte, "	"

Thirty-five miles S.E. of Pichincha is the extinct volcano of Antisana, loftier than Cotopaxi, and overtopped only by Chimborazo and Cayambi. Humboldt mentions three lava streams; we discovered a fourth on the north side, reaching down to Papallacta. The great stream called *Volcan d'Ansango*, can be traced for ten miles, and its thickness as determined by our barometer, is 500 feet, with an average slope of 15°. It consists mainly of a dark, tough, porphyroid trachyte in angular fragments. At the foot of the mountain near Padregal, is a plain containing innumerable rounded, symmetrical hills of volcanic earth. Half way between Antisana and Pichincha the steps of a horse give a hollow sound, showing that the rock is porous and perhaps cavernous. In the same plain is a hot spring (118°) exhaling sulphuretted hydrogen. We ascended Antisana, to the altitude of 16,000 feet, collecting in this ascent the following representative rocks:

Cellular vitreous trachyte, black with few crystals,	(common.)
Fine grained, porphyroid trachyte, dark,*	"
Coarse " " reddish,	"
Compact trachyte, gray, found at snow limit,	"
Porphyroid " iron-stained, " "	"
Fine-grained " "	(rare).
Porous " dark,	"
Fine-grained " with augite crystals,	"
Pumice,	"

Fifteen miles S.W. of Antisana rises Cotopaxi, the loftiest and most symmetrical active volcano on the globe. Every representation, excepting the photograph taken by Farrand, is erroneous. Humboldt made the south slope 52°, and the north 50°. Guzman made the slope 69° 30'! Villavicencio in his *Geografia* makes it 40°; and in a view drawn by Salas, the first artist in Quito, the slope is 35°. Spruce makes it 29°

* This and the preceding are characteristic of the "lava streams."

30′. The true slope of the south side is 30° 45′; of the north, 26° 45′; and of the west and east a little over 30°. Spruce gives 121° as the apical angle of the cone; more correctly it is 122° 30′. On the summit is a circular parapet of scoriæ as on the Peak of Teneriffe. On the east side are signs of an ancient lateral eruption. Cotopaxi is emphatically the pumice-producing volcano. The ash and cinder, sand and pumice accumulations in the vicinity are immense. In one place (Quincherar) they are 600 feet deep. The new road to the capitol which crosses the Chisinchi ridge about half way between Cotopaxi and Iliniza, presents the following section showing the character and relative amount of material successively erupted :

Soil,	1 ft.
Fine yellow pumice,	5 "
Compact black ashes with seams of pumice,	10 "
Fine yellow pumice,	1 " 6 in.
Compact black ashes,	12 "
Fine yellow pumice,	2 "
Compact black ashes with seams of pumice.	

Near Tacunga is the following section :

Soil,	0 ft. 0 in.
Stones and cinders,	5 "
Fine pumice,	0 " 6 "
Stones and cinders,	10 "
Compact black ashes.	

Compare a section at Pompeii :

Soil,	3 ft. 0 in.
Brown incoherent tuff,	1 " 6 "
Small scoriæ and white lapilli,	0 " 3 "
Brown earthy tuff,	4 " 9 "
Whitish lapilli,	0 " 1 "
Gray solid tuff,	0 " 3 "
Pumice and white lapilli,	0 " 3 "

The mud deposited at the foot of Cotopaxi, von Cotta would call a kind of volcanic tufa. The plain of Mulalo is strown with huge blocks of dark trachyte, some of them thirty feet square. They lie in rows; and Visse contends that they are not the product of volcanic eruption. The following are the rocks seen about Cotopaxi :

Pumice, with dark specks of augite,*	(common.)
" pure white,	"
Porous trachyte,	"

* The pumice seen by Castelnau and Bates floating on the Amazons was doubtless brought down from Cotopaxi by the Pastassa.

Very compact trachyte, dark gray,	(common.)
Granular trachyte, whitish with hematite scales,	"
Fine-grained trachyte, reddish, mottled,	"
" " gray,	"
" " dark, very tough,	"
Porous trachyte, iron-stained,	"
" " black,	"
Porphyroid trachyte, black vitreous base,	"
" " flesh-colored,	"
" " fine grained, dark,	"
Obsidian,	(rare.)
Fine-grained trachyte, dark, augitic,	"
" " cellular,	"
Soft, disintegrating trachyte, hardens under water,	"
Feldspatho-augitic rock, reddish,	"
Coarse porphyroid trachyte, reddish,	"
" " " light gray,	"

Tunguragua is a beautiful cone rivaling Cotopaxi; but it is 2,000 feet lower. Spruce calls one of the slopes 43° 15′, and the apical angle 92° 30′. We found the west, east and south slopes 38°, making an angle at the apex of 104°. The west side is covered with fine black sand; on the north is an immense stream of black porphyroid fragments, much resembling the Antisana currents.* At the base of the mountain there is a fine grained ferruginous sandstone; and at Guanandu there is a cliff presenting columns of dark trachyte having a distinct prismatic form. At Baños is a hot ferruginous spring (130°). The last eruption lasted from 1773 to 1780; but Spruce asserts that he saw smoke issuing from the western edge of the truncated apex in 1857. The lithology of Tunguragua is illustrated by the following specimens:

Vitreous trachyte, black with occasional feldspar crystals,	(common.)
" " " vesicular,	"
Fine-grained trachyte, gray with augite crystals,	"
Porphyroid trachyte, banded black and gray,	"
" " dark base, numerous crystals,	"
" " reddish,	"
" " gray,	(rare.)

Altar is the most alpine of the Ecuadorian mountains. From the west it appears to be what it undoubtedly is, a broken down volcano, presenting eight snowy needle peaks surrounding an immense crater. It has not been active since the days of the Incas; but there is a tradition (still living in its Indian name, *capac-urcu*, the chief,) that originally it over-

* Humboldt says that Antisana was the only Quito volcano where he saw anything like a lava-current.

topped Chimborazo, and that after a violent eruption, which lasted eight years, the walls fell in. The plain of Riobamba is covered with fragments of trachyte, the debris of the last cone.

Twenty-five miles S. E. of Riobamba, is the ever active Sangai. Little is known of this busy volcano, as the marshes surrounding it and the great depth of fine ashes on the sides, render it unapproachable. It is constantly ejecting ashes and incandescent stones (LaCondamine adds "sulphur and bitumen,") accompanied by hourly explosions sometimes heard at Guayaquil. It is said to be more active in winter than in summer.

From these examples it will be seen that the products of the Ecuadorian volcanoes are mainly feldspathic. Trachyte abounds throughout the Andes. All the summits which rise above the limit of perpetual snow are trachytic. The trachytes of Bolivia, says D'Orbigny, are always micaceous; those of the equator are cellular, porous, granitoid, granular or compact. Cotopaxi alone produces foam-like pumice.* A most perfectly glassy translucent obsidian is occasionally found on Cotopaxi and Chimborazo. Its sp. gr. is 2·35 to 2·40. Humboldt mentions pitchstone as occurring on Antisana. There are numerous rocks on that volcano, and especially on Tunguragua, which exhibit a black vitreous base resembling pitchstone, but it is anhydrous, (losing only $\frac{3}{1000}$ of its weight by ignition,) and is therefore a soft trachytic glass. A coarse variety, approaching "ribboned obsidian," we found on Antisana. Some of the porphyritic rocks are conglomerate; but the great majority are true porphyries having a homogeneous base. Dr. Hunt calls them "porphyroid trachytes." Many of the specimens would be labeled Andesite by Darwin; but we demand a uniform and more definite definition of the term before using it. They have a black, rarely reddish, vitreous or impalpable base approaching obsidian, with a sp. gr. of 2·59 in pure specimens, and holding crystals of glassy feldspar and sometimes of pyroxene and hematite. They differ from the Old World porphyries in containing no quartz and seldom mica. The absence of basalt as well as the paucity of quartz is noticeable. Granitic rocks, also, so abundant in eastern South America, are rarely visible on the Pacific side, in the neighborhood of volcanoes. But they are only covered by

* James S. Wilson, C. E., in the employ of Ecuador, claims the discovery that "pumice is not a rock produced by volcanic fusion, but simply a rock altered by the solution and removal of one or more of its ingredients by humid heat, probably assisted by gases and acids. Thus the pumice of Pichincha is granitic, and specimens are found showing gradations of change from compact stone to porous pumice." It is remarkable that true trachyte, pumice and obsidian are wanting in the Galapagos only 700 miles from Pichincha. According to Pentland, trachytic pechsteins, obsidians and other vitrified products are very rare in Peru and Chili.

volcanic accumulations. At Cuenca, south of Chimborazo, metamorphic rocks abound. On the east slope of the eastern Cordillera mica-slate is the prevailing rock. The "prodigious beds of gypsum" seen in Chili are wanting in Ecuador. A dolomitic marble occurs near Cayambi.

The valley of Quito is doubtless filled up, like the Bolivian plateaus, with the debris of granitic and ancient sedimentary rocks, but it is now covered by a vast layer of pumice and scoriæ which have been falling from the early tertiary to the present time. Nearly the only fossils brought to light are some pleistocene mammals. At Alangasí, six miles from Quito, teeth of the Mastodon (Andium?) have been found; and in the ravine of Chalan seven miles south of Riobamba, we discovered the femur and patellæ of a Mastodon, the skull of a Horse, and numerous leg-bones not yet identified. They were imbedded in the middle of a cliff (200 ft. high) of the compact tenacious clay resulting from the union of trachytic ashes with water, and were associated with terrestrial shells, identical with living species in the vicinity. The bones were drifted to this spot and deposited (many of them in a broken state) in horizontal lines. It is interesting to speculate upon the probable climate and the character of the vegetation in this high valley, when these extinct mammifers lived.*

Rochester, N. Y., Nov. 10th, 1868.

Art. XXI.—*Observations upon Autumnal Foliage;* by Joseph Wharton.

If chlorophyl, the green coloring matter of leaves, should be, like many other greens, a compound color, it must have for one of its elements a vegetable blue, capable of being reddened by acids.

If the juices of leaves, kept in a neutral condition by the vital force, or by alkaline matter brought in the sap from the earth, should, when circulation ceases, become acidified by the atmospheric oxygen, those juices would then be capable of reddening the vegetable blue of the chlorophyl.

If, however, that vegetable blue should be thus reddened, it ought to become blue again, when exposed to an alkali; or, in other words, if green leaves should be reddened in the autumn in the manner here suggested, by the unresisted action of the oxydizing atmosphere, they ought to return from red to green, if immersed in an alkaline atmosphere.

* See further, on this subject, an article on the heights of the South American Andes of Ecuador, etc., by Dr. Moritz Wagner, in the Berlin Zeitschrift für Allgemeine Erdkunde, xvi, 232, 1864.

Reasoning thus one autumn day about ten years ago, I arranged a wire staging, to stand under a glass receiver, which dipped into a dish of water, and under which was also placed a capsule containing ammonia. Upon this staging I placed in succession a variety of autumnal red leaves, and had the gratification to perceive that in most cases the green color was restored.

The rapidity and completeness of this restoration varied greatly in different leaves ; while those which were covered by a thin and porous cuticle passed visibly from red to green before the eyes, (for instance Sassafras, Blackberry, Maple, etc.), others, whose cuticles were comparable to an impervious varnish, (for instance some of the Oaks,) changed gradually into brown, without showing any trace of green, except sometimes in a few spots where an imperfection in the leaf existed.

In order to determine fully whether the behavior of this latter class of leaves was really owing to the protection afforded to the pulp or chlorophyl by the cuticle, I wounded several such oak leaves in divers spots, and found that although these leaves, when exposed to ammoniacal vapor, became generally brown, each wound became the center of an irregular patch of green.

Of course the final result of exposure of any leaf to the vapor of ammonia, is destruction of all delicacy of tint, and production of a general decaying brown color ; but the restoration of green is perfectly distinct, and this green color endures for some minutes, or even hours, if the leaves are soon enough removed from the vapor.

This simple experiment had more significance for me, when I read, a few years afterward, that the distinguished French chemist Frémy, had actually separated chlorophyl into two distinct substances, one blue, the other yellow.

Frost probably plays no other part in causing the autumnal tints, than merely to arrest the circulation by killing the leaves. When a sharp frost occurs early in the Fall, while the pulp of the leaves is still full and plump, the red colors come out brilliantly, because there is plenty of the blue substance to be acted upon by the juices, then also abundant.

When on the other hand the leaves die slowly and are at the same time slowly dessicated in a late and dry autumn, the pulp becomes so meager, and the skin so dry and hard, that an abundant production of fine red tints is impossible, and brown, the color of decay, predominates.

The connection between arrest or feebleness of circulation and reddened foliage, is well illustrated by the Sassafras, the leaves upon the extremities of whose branches are usually well

nourished and succulent, while the inner leaves—those nearer the trunk—are smaller and weaker. It is not uncommon for a Sassafras tree, which stands alone, to present in the autumn the appearance of a green mass of foliage, illuminated from within by red and yellow lights: this results from the complete change of those feeble leaves in the interior, before the more vigorous outward leaves are in a condition to yield.

An Oak tree, observed last Fall, afforded a similar illustration. Twigs had sprouted from the trunk, and the leaves upon those twigs all reddened long in advance of the leaves upon other parts of the tree. When, shortly after, and long before the general stripping of the tree, those twigs fell, they appeared upon examination to have been detached from the trunk thus early by a process similar to that which separates the single leaf from the plant, and whose first effect had of course been an untimely stoppage of the circulation.*

Leaves which die in the Summer are usually dried out directly, or, if the weather is moist, are quickly rotted; still, it is common enough to see single dead leaves of Gum, Sumac, or Sassafras, splendidly reddened many weeks before a frost.

In June, 1868, I observed leaves of Mahonia upon a sickly twig thus colored, and on July 19th, I found thoroughly reddened leaves of Sassafras and Gum, and leaves of American Poplar and Chestnut of perfect autumnal yellow; all being of course such as by feebleness of, or injury to, the sustaining twigs, had been deprived of their circulation.

It is somewhat remarkable, however, that of the millions of dead leaves which I saw last Summer upon twigs wounded by the seventeen year locusts, not one showed autumnal tints; though I observed upon a number of trees, bearing the brown leaves of the locust-wounded twigs, an occasional leaf of a full autumnal red upon a twig not so wounded.

For the convenience of those who may incline to pursue this subject, I add a compend of some of the principal recent investigations concerning chlorophyl and related matters.

Comptes Rendus, l, 405. Frémy separates chlorophyl, when

* The Medical Press and Circular, of Paris, states that M. Trecul and others have lately been engaged in investigating the cause of the autumnal stripping of trees, and their researches would seem to point to the conclusion that in many plants a phenomenon occurs just before the fall of the leaf, which is not unlike the process which accompanies the shedding of horns in animals. It consists in the obstruction of the proper vessels at the base of the petiole, or leaf stalk. The obstruction, according to an American writer, is caused by the multiplication of cells, which first occurs in the parietes of the vessels. The cells increase and multiply, till at last the vessels are completely choked up in the neighborhood of the insertion of the leaf, and thus a differential plane is formed, across which the leaf stalk breaks, and the leaf accordingly falls.

dissolved in alcohol, into two coloring matters, by submitting it to a mixture of ether and chlorhydric acid; the former takes up the yellow matter, (phylloxanthin,) the latter the blue matter (phyllocyanin,) each liquid having distinctly the yellow and the blue color respectively, which being mixed by shaking together, form a leaf green. The yellow coloring matter of new sprouts, and of etiolated leaves, contains phylloxanthin, capable of being developed into chlorophyl; in autumnal yellow leaves, the phyllocyanin has been destroyed. The yellow matter, Frémy supposes to be more universal and more stable than the blue.

Comptes Rendus, lvii, 39. Châtin and Filhol state that the surface of young leaves is covered with a fatty substance, protecting the tissues from the air, which varnish diminishes toward Fall. This being removed, the leaf becomes dead colored. Deoxydizers (e. g., SO^2) restore red leaves to yellow. Red leaves contain yellow matter deeper in, below the red. Leaves remaining yellow, are so because the oxydation which turns green leaves first yellow and then red, has been arrested in them at the yellow stage. (This appears to me by no means applicable to such yellowed leaves as the American Hickory and tulip Poplar.—J. W.)

Comptes Rendus, lxi, 188. Frémy reports that he obtains pure chlorophyl as follows. By agitating hydrate of alumina with the ordinary alcoholic solution of chlorophyl, a green paste or lac is obtained, a fatty substance which accompanies chlorophyl being left in the alcohol. This green paste being afterward boiled in alcohol, the latter takes up from the alumina pure chlorophyl, which is deposited when the alcohol is afterward sufficiently diluted with water. Chlorophyl thus purified, being boiled long enough with hydrate of baryta, is decomposed into phylloxanthin, (a neutral body, analogous to glycerin,) and phyllocyanate of baryta. The mass of precipitate containing these two substances, being treated with alcohol, the phylloxanthin is dissolved, and is obtained by evaporation in crystals, yellow plates, or reddish prisms. Phyllocyanate of baryta, treated with SO^3, yields its acid, which is insoluble in water, but forms an olive colored solution in alcohol or ether; dissolved in SO^3, or HCl, it gives liquids, which according to their concentration are green, reddish, violet or beautiful blue. Frémy does not consider chlorophyl a simple mixture of its constituent substances.

Comptes Rendus, lxi, 371. M. E. Filhol shows that the treatment of chlorophyl by acids decomposes it, and produces substances not preëxisting. No substance, therefore, got from

chlorophyl, which has been even in a feeble degree subjected to acids, can be considered as a constituent of chlorophyl.

Comptes Rendus, lxi, 436. M. A. Trécul observes what he thinks to be naturally crystallized chlorophyl, in cells in the bark of Lactuca Altissima.

Liebig & Will's Jahresbericht, 1863, p. 561. Stein remarks that the red spots in the flowers of Aesculus Hippocastanum, also the flowers of Aesculus Pavia, which are first yellow then red, are turned green by alcoholic solution of soda. In other red flowers the red is turned green by alkalies, but is turned blue by the acetates of alumina, magnesia, or protoxyd of manganese. This red coloring matter appears to be the same as that of such blue flowers as Hyacinthus botryoides and Centaurea cyanus, which is reddened by alcoholic hydrochloric acid, and then again turned green by alkalies, and blue by the above named acetates. Stein supposes the blue coloring matter to be formed by combination of the red coloring matter with a base, namely lime, since the ashes of cockle contain much lime. (Centaurea cyanus, immersed directly in ammonia, becomes green, apparently by optical combination of yellow produced by the alkali with the blue remaining unchanged.—J. W.)

Jahresbericht, 1865, p. 628. F. V. Jodin finds that green leaves killed by alcohol, or by heating in closed vessels to 100° C., are rapidly bleached when exposed to light and air, but retain their color if kept in the dark.

Journal für praktische Chemie, xcv, 219. Vohl took, in 1856 horse chestnut leaves, which had been killed by a strong night frost, and laid them away in a close stoneware jar with water, so as to allow them to rot in the dark. In 1865, nine years later, he took out those leaves, and by treatment, first with ether, then with alcoholic ether, extracted vegetable wax and chlorophyl, thus proving chlorophyl to be a tolerably permanent body, when not exposed to light or air.

ART. XXII.—*On a Modified Form of the Nitrate of Silver Test for Arsenic Acid;* by CHARLES E. AVERY, Student in the Massachusetts Institute of Technology.

SINCE arsenate of silver is slightly soluble in an aqueous solution of nitrate of ammonium, and readily soluble both in ammonia and dilute nitric acid, it is not easy to detect small quantities of arsenic by means of nitrate of silver, as usually employed, unless the test be applied with extreme care. It

is evident, however, that if the liquid to be tested for arsenic acid,—as for instance the nitric acid solution of a spot or mirror of metallic arsenic,—could be charged with a salt, or acidulated with an acid incapable of dissolving arsenate of silver, it would be possible to test for arsenic without special precautions. At the suggestion of Prof. F. H. Storer, I have tested this idea by experiment.

All acids which I have tested in this regard exert some solvent power; but those having very little solvent action may be used almost as though they had none. I find, in fact, by experiment, that the addition either of acetate of sodium, acetate of ammonium, or Rochelle salt, to a mixed solution of arsenic and nitric acids, is sufficient to ensure the immediate precipitation of arsenate of silver, when ammonio-nitrate of silver is introduced.

By placing a small quantity of a nitric acid solution of arsenic acid upon a watch glass, stirring into it a few drops of a strong solution of either of the alkaline acetates or of Rochelle salt, and then adding a drop or two of ammonio-nitrate of silver, the characteristic brown-red precipitate of arsenate of silver is at once thrown down, even when the solution under examination contains comparatively little arsenic.

The acetates are to be preferred to the double tartrate ; for, unless there be nitric acid enough in the liquor tested to set free all the tartaric acid, white bitartrate of potassium separates on agitation, and obscures the reaction.

Instead of the acetates or tartrate, recently precipitated carbonate of silver may be employed to neutralize free nitric acid in testing for arsenic acid. If the nitric acid solution be poured upon an excess of freshly precipitated carbonate of silver, the red arsenate, instantly formed, shows clearly on the ground of snow-white carbonate ; this is a striking reaction, and therefore a delicate test. Oxyd of silver, when tried in a like manner, gave no results of value.

Experiments made with sulphate, succinate, and nitrate of ammonium, served merely to establish the superiority of the acetates and carbonate, as above described ; and to show that arsenate of silver is less readily precipitated in the presence of sulphate, and especially nitrate of ammonium, than from solutions of either of the other salts employed in my experiments.

When present in relatively large quantity, arsenic acid readily precipitates silver from a solution of nitrate of ammonium and ammonio-nitrate of silver, but the color is uncertain ; the same objection applies to the succinate of ammonium.

The experiments were varied by changing the proportions of

the reagents so that the several results stated above are deduced from many trials. The same tests being tried, with phosphoric in place of arsenic acid, the alkaline acetates gave the best results.

The following quantitative experiments were then tried, to determine the relative solubility of arsenate of silver in solutions of acetates of sodium, Rochelle salt, and nitrate of ammonium. In experiment No. 1, 20 grms. of crystallized acetate of sodium were dissolved in a mixture of 100 c. c. of water and 60 drops of a saturated solution of arsenic acid. In No. 2, 20 grms. of Rochelle salt and in No. 3 a like quantity of nitrate of ammonium, were dissolved in similar mixtures.

Each of the solutions was nearly but not quite neutralized by adding carbonate of sodium ; and ammonio-nitrate of silver was then added to them from a dropping flask. A slight milkiness, due probably to the presence of chlorine in the carbonate of sodium, was produced by the first drop in each of the three solutions ; but this cloudiness had a distinct red tinge in the tartrate solution, (No. 2,) while it was bluish white in the acetate (No. 1) and the nitrate (No. 3). When twelve drops of the ammonio-nitrate had been added, a distinct red precipitate had formed in No 1, (acetate,) and a very strong one in No. 2, (tartrate) ; but no change appeared in No. 3, (nitrate). The precipitate in No. 2, showed white streaks, or layers, at the moment of its formation (probably of bitartrate of potassium), which soon disappeared.

Adding more of the ammonio-nitrate to No. 3, with occasional drops of arsenic acid solution, to keep the mixture acid, a purple cloudiness appeared, which increased up to the sixty-fifth drop, but no precipitate fell.

In a repetition of No. 3, (nitrate,) no precipitate fell until 80 drops of the ammonio-nitrate of silver had been added ; when it reached 85 drops, the precipitate was exceedingly voluminous. In three other experiments, the liquids were acidulated with tartaric acid. In experiment A, 75 drops of a strong solution of arsenic acid, 125 c. c. of water, and 25 grms. of crystallized acetate of sodium, were mixed, neutralized with carbonate of sodium, and tartaric acid added. In B and C, 25 grms. of Rochelle salt and of nitrate of ammonium were respectively substituted for acetate of sodium.

Seven drops of ammonio-nitrate were then added to each of the solutions. In A and B, the red-brown arsenate precipitate appeared ; but in C, no precipitate was formed except the light cloudiness due to impurities.

Boston, Dec. 1, 1868.

Art. XXIII.—*Notices of papers in Physiological Chemistry*—No. II; by George F. Barker, M. D.

5. *On the formation of Sugar in the liver.**

[Continued from page 32.]

(43.)† In a paper on the origin of the sugar of the chyle, published June 28, 1858,‡ Colin calls attention to the large amount of saccharine matter produced in the intestines. A horse, for example, consuming daily 5 kilograms of hay, as much straw, and 3·6 kilos. of oats, obtains from this food, according to Boussingault, 6196 grams of sugar, of starch and of other analogous principles, capable in great measure, of being converted into glucose and dextrin. A fraction of this mass enters the portal vein, goes to the liver, and thus reaches the general circulation; another fraction, mixed with the chyle is absorbed by the lacteals, and poured into the blood; so that this fluid finally receives the whole of the absorbed products. Is it a matter of surprise, therefore, that sugar should be found in the chyle? and can its intestinal origin be doubted? Poisseuille and Lefort have asserted that the sugar found in herbivorous chyle is brought by the lymphatics and the arteries from the liver; though they have given no proof of this singular assertion. To account for the presence of sugar in the chyle they contend, 1st, that it is carried there by the blood and lymph; 2d, that the lacteals cannot absorb it, even when ready formed; 3d, that the chyle is simply an intestinal lymph, to which fatty matters have been added; and 4th, that the glucose found there is in small quantity, much inferior to that existing in other lymphatic vessels. As to the first point, the liquid taken from the great chyliferous trunks passing to the *receptaculum chyli* of a carnivore, as also the fluid drawn from the large lacteal vessels which accompany the mesenteric arteries of ruminants fed on meat, is evidently pure chyle unmixed with lymph; and, as it contains sugar, this sugar must have come from the intestine. To controvert the second assertion, nothing is easier than to show that the lacteals absorb saccharine substances with great facility; since the liquid

* From this point, the range of the discussion widens to include the amyloid function not only of liver tissue, but also of other tissues. The obvious bearing of these facts on the glycogenic theory, is a sufficient reason for noticing them in this connection.

† Through an oversight, paragraphs (43) and (44) in the January number, were prematurely inserted. They should be numbered (55) and (56), and placed in their proper order.

‡ C. R., xlvi, 1264.

taken from a thoracic fistula after a saccharine food, shows a gradually increasing proportion of sugar as the absorption goes on. In the third place, physiologists generally agree in considering the chyle as the product of an absorption effected by the intestinal villæ; they think with reason that the chyle comes from the food because of its fibrin and albumin, its fatty matters and salts. Why does it not derive its sugar also from this source? But lastly, it is not true that chyle contains less glucose than lymph. The authors quoted have compared the one liquid taken from a herbivore, with the other from a carnivore; the chyle from a mutilated and dying cow with the lymph taken from a dog. Colin, on the other hand, as a result of experiments on more than 30 animals, cows, bulls, rams, pigs, and dogs—the two fluids being collected at the same time—finds that the amount of sugar is sometimes equal in both, sometimes unequal; but that in the latter case, the difference is always in favor of the chyle. The absolute quantity of glucose in the chyle is somewhat variable; it is less with herbivora than with flesh-eaters, since in the former the chyle is largely diluted. In the solipeds and in ruminants fed on hay and straw, it oscillates from 130 to 160 milligrams to the 100 grams of liquid; in the carnivora fed exclusively on meat, from 120 to 140. It increases rapidly when the food is rich in sugar; with a dog previously fed on meat, it rose from 137 to 205 milligrams within two hours after the ingestion of a liter of milk containing 40 grams of glucose, and then returned to the normal quantity. In the case of a horse whose chyle, when fed on hay and straw, contained 150 milligrams of sugar in 100 grams, it rose to 214 milligrams in one hour after giving the animals 200 grams glucose in several liters of water; and to 259 milligrams two hours later. Moreover, the activity of digestion affects the amount of sugar. The chyle of a bull, having a thoracic fistula from the mesenteric lacteals, and another from the lymphatics of the neck, showed at first 104 to 110 milligrams of sugar; as the animal became feeble it fell to 84, then to 66, and at death only traces could be detected. Lastly, compared with the lymph, the quantity of sugar varies very little; in a bull, 100 grams of chyle contained 106, of lymph 102 milligrams of sugar; horse A, chyle 149, lymph 123 milligrams; horse B, chyle 141, lymph 112; mare, both 158 milligrams; a dog, chyle 128, lymph 152; a second dog, both 135.

(44.) Poisseuille and Lefort replied to Colin, July 19,* stating that he had evidently confounded the results of separate experiments made by them. His statements refer solely to

* C. R., xlvii, 112.

the experiments on fasting carnivora (Exp. A) where it is stated that "the sugar found in the lacteals comes from the lymphatics of the liver;" nowhere is this fact stated of the herbivora in full digestion. In these animals glucose was recognized (Exp. D) not only in the chyle but also in the blood of the inferior and superior venæ cavæ, in the mucus of the small intestine, in the intestinal walls, in portal blood, etc. It was distinctly stated that the sugar in the intestinal walls might have come from the intestinal contents. As to Colin's results, by which he proves that the chyle contains more sugar than the lymph, in opposition to the opinion they expressed, Poisseuille and Lefort leave the matter to the Commission having the papers to report upon.

(45.) On the second of August, BERTHELOT communicated a paper to the Academy* on the transformation into sugar of various proximate principles contained in the tissues of invertebrate animals. The animal matter which enters into the composition of the vertebrate skeleton is markedly different from that contained in the invertebrate skeleton. In the former it is insoluble in cold water, soluble in alkalies and much resembles albumin; in the latter, two distinct varieties exist, one of which resembles horn very closely, while the other has a remarkable identity with cellulose, the chief constituent of vegetable tissues. Chitin is an example of the former; the substance forming the mantle of tunicate molluscs, of the latter. Both are insoluble in hot and cold water, in alcohol, acetic acid, etc.; are not attacked by concentrated boiling potassic hydrate nor by dilute mineral acids. Neither of them presents any resemblance to albumin. When the tunicate envelop is obtained free from nitrogen, it has the composition of cellulose; chitin however, contains, even when purified, $\frac{1}{15}$ of its weight of nitrogen. The one is an isomer of cellulose; the other has only a certain analogy with it. Thus far, no more intimate bond of union between the chemical functions of these bodies and those of vegetable cellulose had been obtained. Berthelot sought such a connection by boiling for several hours with concentrated hydrochloric acid, the envelop of an ascidian (*Cynthia papillata* Say) then boiling again with a potash solution of 32° B., washing thoroughly, drying and analyzing it. Numbers were obtained identical with those given by cellulose; but since this material is evidently distinct from that substance, not being altered by boiling with dilute mineral acids for many weeks even, he proposes for it the name *tunicin*. When treated in the cold with concentrated sulphuric acid, however, it slowly

* C. R., xlvii, 227.

dissolves; and on dropping the solution into 100 times its weight of boiling water, saturating by chalk, filtering and evaporating, a syrupy liquid, browned on heating with potassic hydrate, reducing the copper-tests, and fermenting with yeast, is obtained. Chitin when treated by the same process, also yields glucose.

(46.) Some experiments on the accurate determination of sugar by the fermentation process in an improved apparatus, were communicated by POISSEUILLE to the Academy on the 6th of December.* The copper-test often fails to give a precipitate in liquids containing sugar; and the saccharimeter is useless when the liquid to be tested is colored. The fermentation test then is the only one left; and this is accurate only when certain precautions are employed. The special apparatus devised by Poisseuille consists of a graduated tube open at both ends, and having a capacity of from 18 to 100 c. c. The upper end is closed with a cork, through which passes a funnel tube with a lateral opening near the bottom; the lower end is enclosed in an india rubber tube, closed below, in which it slides freely, the object being to increase in this way the capacity of the apparatus. This caoutchouc tube is 17 to 18 centimeters long. The amount of sugar in the liquid to be tested having been approximately determined by a copper-test, a suitable graduated tube is selected, a known volume of the decoction is placed in it, some yeast diffused through distilled water is added, the whole is corked and placed in a vessel of water of the desired temperature. As the fermentation goes on, carbonic acid gas is disengaged and forces the liquid up the central tube; it falls again, however, on lowering the rubber tube. When the experiment is concluded, the gas is easily measured, the necessary corrections made, and the amount of sugar calculated. If the contained gas be agitated with a solution of potash introduced through the funnel tube, the amount of carbonic acid evolved may be more accurately estimated by absorption.

(47.) In a subsequent note read Dec. 27,† POISSEUILLE mentions that the liquids used in his apparatus should be previously saturated with carbonic acid gas at a temperature of 32°C. After the fermentation, the apparatus is placed in water at this temperature, and the gas measured. To free the liquids used from contained carbonates, they are slightly acidulated with tartaric acid; after gas ceases to escape, they are placed in the apparatus.

* C. R., xlvii, 906. † C. R., xlvii, 1058.

(48.) On the 10th of January, 1859, BERNARD read a memoir before the Academy,* on a new function of the placenta. "The object of my communication" he says, "is to establish anatomically and physiologically the fact that beside the various uses without doubt subserved by the placenta, it is designed to accomplish the glycogenic function of the liver during the early stages of fœtal life, before this organ has acquired the structure which fits it for doing this work." He had in 1854 recognized the fact that the glycogenic function did not commence until a comparatively late period of intra-uterine life, though from the commencement of organization, the fœtal tissues contain either sugar or glycogenic matter, apparently as a necessary condition of their development. Now it has been demonstrated experimentally that in mammals this glycogenic matter does not come from the mother; a fact obvious enough in birds, where the fœtus is separately developed. Hence this glycogenic function, performed later by the liver, must, in the earlier stages of intra-uterine life, be either diffused through various tissues, or located temporarily in unknown embryonic organs which cease to act when the liver becomes active. Experiment has shown the latter to be the true hypothesis; there exists, even before the liver can act, a true hepatic placental organ, which produces glycogenic matter; and this provisional function disappears at the precise period of intra-uterine life when the liver becomes capable of performing it. The multiple placentas of ruminants were first examined, since they were readily procurable in the *abattoirs* of Paris. But though very numerous experiments were made with calves and lambs at all stages of intra-uterine life, no traces of glycogenic matter could be detected in any part of the placenta. Rabbits and guinea pigs were then used for the experiment; and in the placentas of these animals was a whitish substance formed by the agglomerated epithelial or glandular cellules, which cellules like those of the adult liver, were filled with glycogenic matter. The mass of these cellules seems to be situated between the maternal and the fœtal portions of the placenta; after attaining full development, it becomes atrophied, and disappears as the fœtus approaches birth. The placentas of these animals have therefore two functions: the one vascular and permanent until birth, the other glandular, with a more limited duration. But why the failure with ruminants? Believing that the cause was to be found not in the absence of this function, but in a variation of it, Bernard undertook a re-examination of the question; and this with complete success. A remarkable and

* C. R., xlviii, 77.

unexpected result was obtained; he found that among the ruminants, while the vascular portion of the placenta—represented by the multiple cotyledons—accompanies the allantois and spreads out upon its external surface, the glandular portion of this organ is separate from it, being developed upon the internal surface of the amnion. In rodents therefore, and in other animals having a simple placenta, the glandular and vascular portions of this organ are intermixed; while in the ruminants, on the contrary, these two portions of the placenta are developed separately upon distinct membranes, and can therefore be separately studied during their evolution. By this anatomical disposition, it may be clearly proved that the vascular portion continues to grow until birth; while the glycogenic portion, attached to the amnion, is largest during the earlier periods of gestation, reaching its highest development during the third or fourth month of intra-uterine life; and then, that it gradually atrophies and disappears, so that at birth no trace of this temporary hepatic portion of the placenta exists. During the whole period of growth of this organ, the fœtal liver has neither structure nor function; as soon however as the liver is developed and its cellules begin to secrete glycogenic matter, the hepatic organ of the amnion disappears. These hepatic plates of the amnion appear among ruminants, very early in fœtal life; they are developed on the internal surface of this membrane, beginning near the line joining it to the skin and extending over its entire surface. The presence of glycogenic matter in them may be easily shown at all periods of their development by means of iodine, which colors the contents wine-red and thus defines the cellules. To prepare the glycogenic matter, the amnion is placed in hot water, and the plates are then removed by trituration in a mortar. On boiling the mass in water and precipitation by alcohol, this substance is obtained, exactly as in the case of liver-tissue. The glycogenic matter thus prepared from the amnion has the most perfect identity with that made from the liver; it dissolves in water, giving a milky solution, from which it is thrown down by alcohol and by glacial acetic acid; iodine colors it an intense wine-red,—the color disappearing by heat and reappearing when cool—and it changes into dextrin and fermentable sugar by the action of diastasic ferments, and of acids. Bernard then gives an elaborate account of the histological development of these plates and their subsequent fatty degeneration. The following are the conclusions reached by his researches: 1st, there exists in the placentas of mammalia a function now first announced, which appears to supplement the glycogenic func-

tion of the liver during the early stages of intra-uterine life. This function is localized in certain glandular or epithelial elements of the placenta, which elements in some animals are mixed with the vascular part of this organ, but are separated from it in the ruminantia, forming on the amnion plates which are epithelial in appearance. 2nd, this hepatic placental organ, by permitting the direct study of the production of glycogenic matter in an isolated anatomical element, confirms and completes the statement long ago made, that the formation of starchy matter is a function common to both kingdoms of nature. We see here this matter accumulating round the animal embryo, precisely as in the seeds of plants, it surrounds the vegetable germ. 3d, the glycogenic function in animals, begins at the outset of embryo life, and before the organ in which it is located in adult life is developed: it is then located in a temporary organ belonging to the appendages of the fœtus. 4th, the question arises, is the biliary function which is possessed by the adult liver, also performed by the placental hepatic organ now described? And again, do the same glandular elements of the liver perform both functions, or is there a distinct kind of cellule for each? Bernard thinks that this question may be settled by researches on the embryonic development of these functions now in progress.

(49.) SERRES followed Bernard with some remarks on the glycogenic bodies found in the umbilical membranes of birds.* In the course of the second or third day of incubation, as is well known, a vascular membrane covering the entire surface of the vitellus, is developed. These capillary vessels originate from separate centers called the sanguineous points of Wolff; they gradually extend their ramifications and thus form patches of radiating vessels, which anastomose about the thirtieth or fortieth hour forming a beautiful vascular network. Between these sanguineous patches there are small glandular bodies covering the entire surface of the umbilical membrane. Under the microscope they may be detected as early as the twenty-fifth hour of incubation, being distinguished by their white color from the vascular patches; they are more distinct about the 35th hour. More than five hundred of these bodies have been counted; they continue to increase up to the sixth day when they are hidden by the vascular network. The nature of these bodies as well as the function which they perform had thus far not been made out. After listening to the remarkable paper of Bernard, however, Serres could not doubt that these bodies were completely analogous to the glycogenic

* C. R., xlviii, 86.

glands of the placenta; birds being a class of animals in which the placenta is represented in part by the umbilical membrane, in part by the allantois. May it not be asserted therefore, that like mammals, birds also have a transitory liver; especially since the inverse relation of this organ to the actual liver is also true of them? The liver in birds does not act till the 11th or 12th day of incubation; and precisely at this time the umbilical membrane is replaced by the allantois which contains no glycogenic glands.

(50.) A second paper by BERNARD was presented to the Academy on the 14th of April,* on the relation of the glycogenic matter to the development of certain fœtal tissues before the appearance of the liver function. The object of his researches was to ascertain what particular histological elements are accompanied in their development by glycogenic matter. For this purpose the organs examined were divided into two classes: 1st, the exterior or limiting organs, comprising the cutaneous and mucous tissues; and 2d, the interior or contained organs, including the osseous, muscular, nervous, and glandular tissues. On examination, Bernard found that the first class of tissues, i. e., all exterior epithelial membranes, whether constituting a mucous or a cutaneous surface—contain glycogenic matter at certain periods of fœtal life. In the cutaneous surface, this substance is found infiltered into the tissues of the skin, as well as collected in the cellules of the epithelium which covers it. Certain animals, as the pig, show this very clearly; while with the rabbit, the cat, and the calf it is more difficult to recognize. The existence of the glycogenic matter in the skin of a fœtus may be demonstrated by scraping it with the blade of a sharp knife, and examining the matters removed under the microscope. Among the histological debris are seen the cellules both containing and surrounded by granular matter which is turned wine-red in color by an acidulated solution of iodine. In this way, the disposition of the glycogenic matter in the skin at all periods of development, may readily be studied.† This microscopic evidence has always been confirmed chemically, by making a decoction of the tissue; an opaline solution is thus obtained, which is colored wine-red by iodine, and is precipitated by alcohol and by glacial acetic acid in ex-

* C. R., xlviii, 673.

† To show to the eye the distribution of the glycogenic matter, Bernard places the entire fœtus in an acidulated alcoholic solution of iodine. The horny extremities, the cutaneous orifices—as the anus and the nasal openings—the eyelids, the ears, and the cornea are most colored. The glycogenic matter in the placenta may also be shown in this way.

cess; it is also changed into sugar very readily by the action of acids and ferments, and in a word, possesses all the characters of that obtained from the liver or the placenta. The horny appendages of the skin, too, contain glycogenic cellules, which disappear as development progresses. In the skin itself, the glycogenic matter disappears rapidly; being absent toward the third or fourth month of intra-uterine life, in calves 25 to 30 centimeters long, in which well defined epithelium is present. Even when absent from the cellules, it is found infiltrated into the skin. Mucous surfaces also, at certain stages of development, show glycogenic cellules. With embryo pigs, calves, or lambs 3 to 6 centimeters long, they may be observed in the mouth, tongue, pharynx, stomach, large and small intestine, occurring in the epithelium surrounding the villosities. The mucous surfaces of the air passages, and also of the genito-urinary passages show the same fact. It thus appears that all the exterior limiting surfaces possess during fœtal life, before the epithelium is fully developed, a glycogenic evolution. Of serous membranes however, the same cannot be said; no glycogenic matter having been found in the epithelium lining the pleura, the peritoneum or the arachnoid. With regard to the internal or contained tissues, they form a separate group, being with few exceptions, unaccompanied by glycogenic matter during their development. The osseous and nervous systems contain no glycogenic matter at any stage; the brain, the spinal cord, the bones—freed from periosteum—and the cartilages, not only in the human fœtus, but in that of the calf, sheep and rabbit, though examined in many ways and at all periods of growth, gave no result. Muscular tissue however, appears to form an exception, since it contains glycogenic matter; but the arrangement of this matter is different from that just noticed. In the very young embryo of the calf, for exampie, 2 to 4 centimeters long, embryonic cellules not colorable by iodine are found in the positions soon to be occupied by muscular tissue; a little later, when the fœtus is from 15 to 20 centimeters long, and when the histological elements of the muscle appear, the muscular fiber is seen as a tube containing nuclei mixed with a granular matter colored red by iodine; this is best seen in the fœtus of the cat. As the fiber develops it soon becomes striated; but the glycogenic matter though lessened in amount is not absent, but seems infiltrated into the tissue. In no case did this glycogenic matter appear organized, nor was it contained in cellules. This substance is also present during the development of the smooth muscles of the heart and of the intestines; in the fiber itself it is sometimes diffi-

cult to demonstrate this, but with a decoction of the tissues the reaction is easily obtained. This glycogenic matter remains in the muscular tissue during the entire period of intra-uterine life, and disappears very rapidly after birth by muscular and respiratory action. The glandular system too, contains during fœtal life no glycogenic matter; the salivary glands, the pancreas, the glands of Lieberkühn, the spleen, and the lymphatic glands having been examined. One glandular organ, the organ which in after life performs the glycogenic function, must be excepted. Though in its evolution, the liver is not accompanied by glycogenic matter, yet toward the middle of fœtal life it becomes histologically developed and acts as a biliary and glycogenic organ. It seems designed therefore, to continue in the adult a fœtal function previously performed by other and temporary organs. Glycogenic matter then, plays as important a part in the organic development of the fœtus as it performs in the nutritive function in adults. "We know in fact that it ceases to be produced in the liver whenever any morbid condition arrests the nutritive function. The substance then which effects the evolution of the fœtal organs continues to be concerned in their nutrition in the adult. This fact establishes a direct connection between organic development and those nutritive phenomena which under various aspects, are only a continuation of it." The phenomena of nutrition in the adult may therefore be elucidated by studying the phenomena of fœtal evolution.

(51.) A paper by ROUGET was presented to the Academy April 18th,* calling attention to previous memoirs communicated to the *Société de Biologie*, in which he had shown that the amylaceous substance in the amnion and placenta is not the product of a peculiar organ and is not contained in special glycogenic cellules, but occurs in the more or less modified epithelial cells of these membranes. Farther researches upon other epitheliums had detected this substance in the epidermic cells of the skin, the soft palate, the tongue, the stomach, and in all the cylindrical cells of the epithelium covering the surface of the large, and the villi of the small intestine. With certain animals, all the intestinal epithelium is filled with amylaceous matter three or four days before birth; though at this time the liver, completely developed for a long period, furnishes this matter abundantly. Finally, finding epithelial cells containing glycogenic matter on the lingual and vaginal mucous membranes even after birth, Rouget concludes that the presence of amylaceous matter in any tissue does not argue a special

* C. R., xlviii, 792.

function, but is simply due to the peculiar constitution of the tissue itself. From these facts it is clear that to the proteic and fatty substances of food, now regarded as the only ones which form animal tissues, must be added amylaceous matters, which form tissues as truly in the animal as in the vegetable kingdom.

(52.) In a letter from SCHIFF, read to the Academy May 2d,* while he agrees with Bernard that a portion of the granulations in the hepatic cellules is animal starch, he claims to have discovered this fact himself in 1856, and to have published it in the Archives de Tübingue for 1857, in a communication dated the 18th of March. Two sorts of granulations surround the nucleus in the hepatic cellules. The first sort are large, have well marked outlines, are almost black in color, soluble in alcohol and ether and become diffluent in acids and alkalies. From 8 to 20 of these are contained in a single cellule. They seem to be fat globules. The second sort are very much smaller, are perfectly rounded, the contour being distinct though pale; they are insoluble in alcohol and ether, take a brownish-yellow color with an acidulated tincture of iodine, and resemble in general the starch of the compositæ, as the dahlia and arnica. They are much more numerous than the others, and were regarded in 1857 as animal starch, for the following reasons: (1) when the liver continues to produce the glycogenic matter, but the ferment fails in the blood so that it is not converted into sugar, the hepatic cellules become enormously distended with this substance; (2) when placed in a liquid containing a ferment, these cellules gradually diminish, while the liquid becomes charged with sugar; the action ceases when the cellules are empty; (3) with batrachians normally, and with mammals and birds, whose liver is saccharine at death, the globules are very numerous; the number however, is less than with batrachians in winter; (4) the number of globules at death is always related to the amount of sugar which the liver can furnish; (5) in passing into sugar, these globules become yellowish drops, soluble in water, insoluble in alcohol; evidently animal dextrin; (6) when in the spring the ferment reappears in the blood of frogs, the globules diminish and the hepatic cellules are filled with these drops, and the liver changes color, passing from dark brown to yellowish or reddish; (7) this change of color takes place at different periods with different species; with *Rana esculenta* it is very late, the liver not becoming saccharine in Switzerland till the end of May; adults pass through it sooner than young animals, females earlier than males; (8)

* C. R., xlviii, 880.

elevation of temperature alone will not produce the ferment and transform the starch; a large number of frogs were kept for more than six months and no sugar was formed though the hepatic cellules were full of starch; (9) in some cases these globules may be absorbed without producing dextrin or sugar; they appear to suffer a change which gives rise to oxalic acid; (10) the diseased livers of mammals, of birds and of frogs which contain no starch, are much darker than those in which the glycogenic transformation is carried on; (11) during hibernation, both the ferment and the hepatic starch are present, though the latter is diminished in amount; (12) nitrogenous tissues treated with cane sugar and sulphuric acid become yellow and then reddish-purple; since therefore the walls of the hepatic cellules and not their contained globules, are colored by this treatment, the latter do not contain nitrogen. Bernard's glycogenic matter according to Schiff, is not a pre-existant anatomical element, but a product derived from this by the processes employed.

(53.) Bernard followed this paper by a recapitulation of the dates of his own discoveries.* First, in 1854, he announced the existence of glycogenic matter, under the qualified name "a sort of animal starch," in various fœtal mammalian tissues, though the substance itself was not then isolated. At the same time, he compared at length, the part which saccharine and amylaceous matters play in the organic evolution of animal and vegetable tissues, and concluded with the opinion that these substances seemed to enter as an essential condition of development of the tissues of both kingdoms of nature. Second, in 1855, he published an experiment fundamental to the glycogenic theory; showing that when the sugar of a healthy liver was removed by washing, the saccharine substance was renewed; thus proving that the sugar is not formed by the splitting up of certain blood elements, but by a fermentation analogous to that taking place in vegetables. Third, in 1857, the isolation of the glycogenic matter was communicated to the Academy on the 23d of March; and, since these experiments, there for the first time described, are referred to in Schiff's paper of the 18th of March above mentioned, it is evident that his paper was antedated and is actually posterior in date to this. The glycogenic matter was here called *amidon animal*; and it was shown to be an isomer of vegetable starch, having all its physical, chemical, and physiological properties, changing to dextrin and sugar by acids and ferments, rotating the polarized ray, etc. The existence of the ferment both in the liver-tissue

* C. R., xlviii, 884.

and in the blood was there shown. The mechanism of the function had been announced before Schiff's experiments appeared. "M. Schiff says himself that he agrees with me; but he thinks that he has more accurately distinguished and located microscopically the hepatic starch, and so has proved my views better than I have myself. If this be so, I cannot but be satisfied; but I see not how this gives him any claim to priority."

(54.) On the 30th of May, ROUGET communicated another paper to the Academy,* on the amorphous amylaceous matter contained in the vertebrate and invertebrate fœtal tissues. This substance—for which he proposes the name *Zoamylin*—is not granular, but consists of a plasma holding in suspension fatty or nitrogenous granulations. Moreover, ossifiable cartilages must be added to the embryonic tissues containing amylaceous matter; though this is not found in the substance of the cartilage, but only in the cells, which in a fœtal lamb 1½ to 2 months old, are colored rose-violet with iodine. With this amylaceous plasma too, the epithelial cells of the digestive, respiratory and genito-urinary passages, of the interior of the eyelids and even of the cornea, are filled. With young ruminant embryos, the cartilaginous, muscular, and epithelial elements of which contain zoamylin, no trace of glycogenic cellules appears on the surface of the amnion. When these are present their mode of development, their form, constitution and general appearance are precisely like those of the cellules of the horny layer of the epidermis; and hence prove the amnion to be an extension simply of the skin. The presence of amylaceous matter in the amnion and placenta, therefore, is not a special case, since all fœtal tissues contained it. No new hepatic organ exists, nor has the placenta any new function. The presence of this substance is the evidence, not of a new function in an organ, but of a new property of tissues. The production of sugar is not the object but the consequence of the existence of zoamylin in the organism. The sugar accumulated by the urinary secretion in the allantoic and amniotic fluids, is a result of the destruction of the fœtal zoamylin, precisely as urea is produced by the metamorphosis of proteic bodies.

(55, 56.) Already given as paragraphs (43) and (44).

* C. R., xlviii, 1018.

(*To be concluded.*)

ART. XXIV.—*A New Meteoric Iron—"The Wisconsin Meteorites"—with some remarks on the Widmannstätian Figures;* by J. LAWRENCE SMITH, Louisville, Ky.

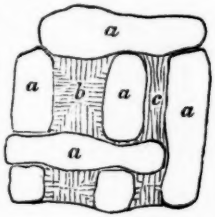
THESE meteorites were first brought to my notice by Mr. I. A. Lapham, of Wisconsin, and his attention was called to them by Mr. C. Daflinger, Secretary of the German Nat. Hist. Society of Wisconsin. They were discovered in the town of Trenton, Washington county, Wisconsin, and I have called them the "Wisconsin meteorites." Up to the present time, fragments have been found, indicating that these meteorites were of the same fall and separated at no great elevation. They were found within a space of ten or twelve square yards, very near the north line of the 40 acre lot of Louis Korb, in latitude 43° 22′ N., and longitude 88° 8′ west from Greenwich, and about 30 miles northwest of Milwaukee.

They were so near the surface as to be turned up with the plough; they weigh 60, 16, 10, and 8 pounds respectively, and present the usual pitted and irregular surfaces.

The largest of the meteorites in i s extreme dimensions, is 14 inches long, 8 inches wide, and 4 inches thick, weighing 62 pounds. Its specific gravity is 7·82, and composition,

Iron	91·03
Nickel	7·20
Cobalt	0·53
Phosphorus	0·14
Copper	minute quantity
Insoluble residue	0·45

A polished surface when etched gives well marked Widmannstättian figures. There is something, however, peculiar about the markings on this iron, which is doubtless common to other irons, but which has heretofore escaped my observation, and I cannot discover, in a hasty investigation, that it has been noticed by others. My attention was called to this peculiarity by Mr. Lapham, on a slice of the meteorite I sent him etched; should these markings be entitled to a separate notice, I propose calling them *Laphamite markings.* The little drawing accompanying this, which is on a somewhat exaggerated scale, will show what they are.



The Widmannstättian figures are *a*, bright metallic, with con-

vex ends and sides ; *b c*, of a darker color, are the other markings, usually smaller and with the sides and ends concave. The material of which these dark figures are composed seems to have enveloped the lighter colored portion, which serves to make the dark lines so beautifully conspicuous. A good pocket glass will show that the darker figures are striated, with lines at right angles to the bounding surfaces. When the figure is nearly square, the lines extend from each of the four sides, but when much elongated, as at *c*, they are parallel with the longer sides. Often these lines do not reach the middle of the figure, where only a confused crystallization can be detected. In the interior of the elongated figures, the lines are quite irregular, often running together, and showing a striking resemblance to woody fibre. The nature of these markings may be easily understood. They indicate the axes of minute columnar crystals, which tend to assume a position at right angles to the surface of cooling.

These markings may have been observed by others ; and as soon as the subject can be examined on other irons, a better conclusion can be formed.

SCIENTIFIC INTELLIGENCE.

I. PHYSICS AND CHEMISTRY.

1. *On the wave lengths of the metallic rays.*—THALÉN has published an extended memoir on the wave lengths of the spectral lines of the elements. The author's work does not present any new measurements, but is based upon those made by Angström, which had already been employed for the purpose of interpolation by the writer of these notices. The method of proceeding was however new. Each luminous ray, the wave length of which was to be measured, was in the first place entered either upon Kirchhoff's chart, which extends from A to G, or upon a new chart by Angström and Thalén, extending from G to H. These rays were then transferred to the normal plates of the spectrum furnished by Angström, and finally were entered upon the charts published with Thalén's memoir, each being placed according to its wave length. In some cases the graphical method was employed. The description of the process employed in determining the wave lengths is by no means clear. The spectroscope used was provided with large telescopes, and with a prism of bisulphid of carbon with a refracting angle of 60°. The number of elements examined amounted to 45 ; of these 23 were in the metallic state, the others being in the form of chlorids. One important result obtained by the author is the proof that the sun's

atmosphere contains titanium. The following elements had, so far as the writer knows, not before been examined with the spectroscope; glucinum, zirconium, erbium, yttrium, thorium, uranium, titanium, tungsten, molybdenum, and vanadium. Appended to Thalén's memoir is a chart upon which the spectra of the different elements are entered upon the plan first employed by Mr. Huggins, so that all the spectra are upon one sheet with the normal spectrum at the top. It must be borne in mind, however, that the lines upon Thalén's map are entered according to their wave lengths and not upon an arbitrary scale. The memoir contains, also, a complete table of the wave lengths of all the lines of the elements examined. With respect to the numerical values of these wave lengths the writer will only remark that they differ widely from those determined by himself in the discussion of Mr. Huggins's scale, in the present number of this Journal.—*Nova Acta Reg. Soc. Scient. Upsaliensis. Series tertia*, vol. vi, fasc. II, 1868. W. G.

2. *On spectral analysis.*—In another memoir on spectral analysis, published in 1866, but which has just reached us, Thalén has given what amounts to a complete history of, and treatise on, the subject. The memoir contains what has long been wanted,—maps of the spectral lines of the elements as seen with a single prism of bisulphid of carbon with a refracting angle of 60°. These maps give the principal lines for each element. They are all upon a single sheet, upon Mr. Huggins's plan, with the solar spectrum at the top for comparison, and with a scale of millimeters. A prism of the bisulphid of 60° has become a sort of normal or standard, easily and cheaply obtained, and extremely convenient for common use and reference. Thalén's chart is therefore a most acceptable addition to our resources, and will, we hope, be published separately.—*Upsala Universitets. Arsskrift.* W. G.

3. *On a normal spectrum of the Sun.*—FIZEAU has presented to the Academy of Sciences, on behalf of the author, A. J. Angström, a new atlas of the solar spectrum. This atlas contains six detailed charts, representing different parts of the solar spectrum, drawn from new observations upon which their author has spent five years. The map contains also a description of the violet portion of the spectrum between G and H, which was wanting in the chart of Kirchhoff and Hofmann. Upon these charts the lines are entered simply according to their wave lengths, a method which Fizeau attributes to Angström. That the new charts will prove of the greatest value and interest cannot be doubted. With respect to the originality claimed for their construction, it may be remarked that the method was first proposed by Billet, (Traité d'Optique, vol. i, p. 47,) and that the first extended chart constructed in accordance with it, was presented by the writer of these notices to the National Academy of Sciences, Aug. 7th, 1866. This chart contained 87 lines.—(*This Journal*, vol. xliii, Jan. 1867.) *Comptes Rendus*, lxvii, 946. W. G.

4. *On the red protuberances from the surface of the sun.*—In verifying the observations of Lockyer and Janssen upon the light

of the solar protuberances, Secchi has made some new observations of interest. One protuberance was observed perfectly detached from the sun's border, the ray C being prolonged at both ends by the continuation of the dark ray. At another point the ray C appeared to touch the edge of the sun's disc. Another protuberance appeared and disappeared at intervals. One fact, showing the abundant presence of hydrogen, is that the ray C disappears almost all round the sun, at the same time that the ray F becomes much feebler.

Lockyer finds that the protuberances are simply local accumulations of a gaseous envelope, which completely surrounds the sun. The thickness of this envelope is about 5000 miles, (8000 kilometers,) and it is wonderfully regular in its entire contour, its distance from the sun being sensibly equal at the pole and at the equator.

Secchi gives the thickness of the envelope as 15 seconds in its thinnest part, and thinks that it may be at least 30 seconds on the average. The yellow line near D, as remarked by other observers, is not a hydrogen line, and does not correspond to any dark line in the spectrum. On applying the spectroscope to the examination of Jupiter, Secchi found that the dark band in the red does not coincide with the band C, which we see in our atmosphere. The same astronomer has had opportunities of studying the spectra of several meteors. One of them exhibited a discontinuous spectrum, the principal luminous rays being red, yellow, green and blue, and very brilliant. In the cases of two other very brilliant meteors, the magnesium ray (*b*?) was superb.—*Secchi in Comptes Rendus*, lxvii, 1018, 937, 1123. *Lockyer in the same*, lxvii, 949.

W. G.

5. *Further observations on the spectra of some of the stars and nebulæ, with an attempt to determine therefrom whether these bodies are moving toward or from the earth, also observations on the spectra of the sun and of comet II*, 1868.—Under the above title Mr. Huggins has brought together a number of interesting and important contributions to astronomical physics and chemistry. In an introduction to the memoir the author discusses the proposition first stated by Doppler in 1841, that the color and intensity of an impression of light, and the pitch and strength of a sound will be altered by a motion of the source of light or sound, or by a motion of the observer, toward or from each other. The introduction contains a concise and clear statement of the theory of the change in refrangibility of light produced by the motion of the observer, or of the luminous body, contributed by Mr. S. Clerk Maxwell. The apparatus employed by Mr. Huggins consisted of an equatorial by Alvan Clark, with an eight inch objective, and a peculiarly constructed spectroscope, the dispersive power of which was equivalent to that of about six flint prisms of 60° and one of 45°. It is only by means of an instrument having a very high dispersive power, that the small difference in refrangibility produced by a small change in the wave length can be measured. With this spectroscope observations were made of the great neb-

ula in Orion and of Sirius. In the case of the nebula, it was found that the brightest of the three lines visible, still exactly corresponded with the brightest of the nitrogen lines seen in the spectrum of the light of the induction spark, taken in pure nitrogen at a tension a little less than that of the atmosphere. The line in the nebula was single, while the nitrogen line is double. When, however, the induction spark was made to pass in front of the object glass of the telescope, the nitrogen line appeared single like that in the nebula. Mr. Huggins calculates that if the line in question be due to nitrogen the nebula is not receding from us with a velocity greater than ten miles per second, as this motion added to that of the earth's orbital velocity would have caused a want of coincidence that could be observed. But if the nebula be approaching our system, its velocity may be as much as twenty or twenty-five miles per second, as part of its motion would be masked by the motion of the earth in the opposite direction. The coincidence of a second line in the spectrum of the great nebula with Fraunhofer's line E was also fully confirmed by the new spectroscope, which increases the probability that this line is due to hydrogen. The author could find no terrestrial line corresponding to the third line of the nebula.

The great intensity of the light of Sirius and the four strong lines in its spectrum, render it well suited for examination. The author selected the line F, and found in numerous comparisons the refrangibility of this line slightly lower than that of hydrogen. From the amount of this difference in refrangibility, taking into account the facts that at the time of observation, the earth was moving from the star with a velocity of about 12 miles per second, Mr. Huggins finds that there is a probable motion of recession of Sirius from the earth amounting to 29·4 miles per second. On examining the spectrum of a solar spot, the author found as he had previously done, that there was a distinct increase in the thickness of Fraunhofer's lines. There was no absorption line in the spectrum of the umbra, which was not present in that of the sun's normal surface, nor was any ordinary solar line wanting.

The spectrum of the comet discovered by Winnecke and by Becquet on June 13th, 1868, was also examined. With two prisms of 60° the spectrum consisted of three very broad bright bands. In two of these the light was brightest at the less refrangible end; the third was of nearly uniform brightness, perhaps somewhat brighter in the center. The bands could not be resolved into lines. The spectrum of Brorsen's comet consisted of three bright bands and a continuous spectrum. By careful comparison with the spectrum of carbon under different circumstances, Mr. Huggins believes that he has shown that the light of the comet II of 1868, is identical with that emitted by highly heated vapor of carbon.—*Phil. Transactions for* 1868, p. 529. W. G.

II. MINERALOGY AND GEOLOGY.

1. *Recherches Anatomiques et Paléontológiques pour servir à l'histoire des Oiseaux fossiles de la France;* par A. MILNE EDWARDS. Tome I. Paris, 1867. Avec un Atlas en 40 Planches, 1–96.—In 1866 the French Academy of Sciences awarded to this work the great prize of physical sciences for 1865; and from the character of the first volume, which is before us, it was a well deserved reward. The difficulties of the subject are considerable; the want of precise osteological characters applying to the class of Birds as a whole, compelled the author to investigate this subject anew. For this purpose he brought together the essential parts of the skeletons of no less than 800 species of living Birds, representing the principal ones and their types. The sternum, skull and bill, which have been mainly employed in framing present classifications are only rarely found fossil, and when found, are usually so fragmentary as to be almost valueless. The author was therefore compelled to search among the bones of the limbs, (these are often found in an admirable state of preservation,) but presenting such apparent uniformity of character, for structural details, which had escaped his predecessors. This task he has accomplished most successfully, and we now have for the class of Birds, a work which fills what had been a great gap in our paleontological literature. Milne Edwards, Jr., calls special attention to the value of the tarso-metatarsal bones, from which he has attempted in many cases a reconstruction of the bird, based upon the important part which the foot plays in our classifications of Birds; he even goes so far as to assign to this part of the skeleton a value as great for Birds as the dental system is for mammals.

The material originally at his command was not extensive, for collections of fossil birds are not found in the great museums of Europe; what there was on hand in these and several private collections in France were all carefully examined. In addition, he undertook himself extensive explorations mainly at Sansan and in the Department of l'Allier, and succeeded in the course of four years in bringing together a more extensive collection than that of any public museum, composed of over four thousand specimens, from the principal quaternary and tertiary deposits of France. It was however mainly in Auvergne, on the shores of the ancient lakes of that district, then inhabited by an immense number of birds, that the greater part of the remains were found.

The principal modifications of the representatives of the class of Birds which our author notices, he considers as plainly showing that we cannot account for the disappearance of the species living at the time of the quaternary period, by any other causes than those which have extirpated the Dodo from Mauritius, the Pezophaps from Rodriguez, the Dinornis from New Zealand, and the Alca from our own coasts. He finds in the caverns of the quaternary period no generic type not still represented in the

fauna of our day, most of the species even being identical with those now living, though many of the species inhabiting France at that period are only found now in the Arctic regions. This he considers a strong argument in favor of the prevalence of a colder climate than at present during the quaternary period.

Among the tertiary Birds no species is identical with those of the present period; several special generic types occur, all of which belong to families now existing; many of the specific types of that time, forming groups which are scantily represented in our day, play a more important part, such as the small family of Flamingoes. Pelicans, Ibis, Flamingoes and gallinaceous birds of large size, analogous to the East India species, lived during the breeding season along the shores of the ancient lakes of Auvergne, as is proved by their eggs, which are found well preserved side by side with the bones of newly hatched young. This and the general character of the avifauna, furnish fresh arguments in favor of the opinion of those who consider the climate of Europe to have been much warmer during the tertiary period than at the present time.

The present volume contains the osteological studies on living birds, which the author proposes to apply in turn to each of the great families of which he has found fossil representatives; he has thus far treated of the "Palmipedes, Colymbides, Longipennes, Totanides and Ceronides; with these the first volume closes. The plates, ninety-six in number, are remarkably well drawn and printed; the iconographic part of the work will prove of great value to Paleontologists, furnishing a starting point for the determination of osteological characters, with an abundance of detail, which cannot fail to be of the greatest service for future discoverers, giving us a complete work on ornithological paleontology, to which the earlier memoirs of Brandt and Owen make such a fitting introduction. A. A.

2. *Report on recent Explorations in the Gibraltar Caves;* by Capt. Fred. Brome.—The explorations recorded in this communication were conducted principally in "Martin's" and St. Michael's Caverns.

Martin's Cave opens on the eastern face of the rock, below O'Hara's Tower. It is an ancient sea-cave, though now upwards of 700 feet above the level of the Mediterranean. The excavations in this cavern were commenced on the 23d of June, and continued till the 22d of July. There were no traces whatever of any previous attempts at exploration. The first operation was to excavate the dark earth all along, close to the south side, which is from six to three feet in depth. At this depth the diggers came upon a stalagmite floor of varying thickness. Here, after a few hours' work, were found deposited two portions of a lower jaw, supposed to be human; about two bushels of bones of ox, goat, sheep, rabbit, &c.; several bones of birds and fish; two bushels of broken pottery of the rudest or unmarked kind, 57 pieces ornamented; 61 handles and pots; 6 stone axes and 70 flint knives; 1 excellent

flint core; 20 lbs. of flint chips; 12 pieces of worked bone; a portion of an armlet and anklet; 10 lbs. of sea shells, and a few land shells, together with three rounded pebbles. On the north side the same class of objects were met with, and in a small chamber on this side, under five or six feet of earth, Captain Brome's son came upon a small chamber containing two ancient swords, one partly imbedded in stalagmite, and both much injured; and on a subsequent occasion, a small enamelled copper plate was found, which appears to have had a design upon it of a bird with its bill open, in the coils of a serpent. The colors are bright, and the object is beautifully made. These interesting relics have been referred by Mr. Franks to the eleventh or twelfth centuries. Excavations were then made in a cavern, situated on the same face of the rock, but a little to the south, and at a higher level than "Martin's" Cave, and named by Capt. Brome the "Fig-Tree Cave," in which similar rude works of art, consisting of fragments of pottery, flint and stone implements, &c., were found.

Captain Brome's greatest interest, however, was centered in "St. Michael's Cave," in which, day after day, numerous human remains were found, some imbedded in the stalagmite, others loose, associated with stone axes, flint chips, and flint knives of the smallest size hitherto met with in the Gibraltar caverns.

On the north side of the upper chamber in St. Michael's Cavern, on breaking up a thick stalagmite floor, a small aperture was discovered. When this had been enlarged sufficiently to admit of Captain Brome's entrance, he found a series of passages and caverns, the extreme traveling distance of which from the entrance was exactly 200 feet. There were no means of access to it, excepting by the aperture by which Captain Brome entered. The walls were snow-white, and the pillars and stalactites of the most variable and fantastic forms. Some of the latter, with the thickness only of a goose-quill, were five feet long! The bearings of the cavern generally run N.W. At the south end of this cavern a perpendicular fissure was discovered, through which came a strong wind. The fissure was about nine inches wide, but one of the men (military prisoners) employed was found small enough to creep through it. He returned with a wonderful story of what he had seen. On the next day, accordingly, Captain Brome sent in one of his own sons, about twelve years old, who entirely corroborated the statements previously given, viz., that there were three caves, the first very small, and about twelve feet from the narrow entrance. At some distance further there was another, about twenty feet square, and still further, a cave as large as the upper St. Michael's first chamber. The distance traveled is 250 feet from the entrance, which, added to the distance (200 feet) traveled in the first discovered cabin, make a total of 450 feet of hitherto wholly unknown caverns in so familiar a locality as the often visited cave of San Migael.

At the date of his last advices, Captain Brome was continuing the exploration of St. Michael's Cavern, with every prospect of

further interesting discoveries. But, as he says, "his surmises, that the unexplored caves would yield the same relics as the Genista Cavern, have been verified, and the fact is nearly, if not quite established, that at a former period all the Gibraltar caverns were tenanted by a race having uniform habits of living."—*Brit. Assoc. Rep. for* 1867, 56, 1868.

3. *On Calamiteæ and Fossil Equisetaceæ*; by WILLIAM CARRUTHERS, F.L.S., F.G.S.—After describing the structure of the recent *Equisetaceæ*, the author gave an account of the internal structure of the various fossil stems which had been referred to this family. True *Equisetaceæ* were rare as fossils, and the stems of *Calamites* were very unlike anything known among living acotyledonous plants. The most important characters were obtained by botanists from the fructification. The author had obtained, through the kindness of Dr. Hooker, sections of vegetable structures prepared by Mr. Binney, whose extensive acquaintance with coal-plants was well known. In some of these he had discovered fruits which belonged to *Calamites* so beautifully preserved that the most minute details could be determined, and with the help of his diagrams he described their structure, and illustrated the various points in which they agreed with, and differed from, the fruits of *Equisetaceæ*. He then described the foliage which had been found connected with *Calamites*, and which had been named *Asterophyllites;* and he showed that as similar fruits had been found associated with *Annularia* and *Sphenophyllum*, which differed from *Asterophyllites* only in the amount of cellular tissue spread out on the veins, there could be no doubt that these also were the foliage of members of this large genus or tribe of plants.—*Ibid.*

4. *Geological Map of New Jersey;* by GEORGE H. COOK, State Geologist, and JOHN C. SMOCK, Assistant Geologist.—This new Geological Map of the State of New Jersey contains the results of the recent Geological survey of the State, under the direction of Prof. Cook. It appears to have been made with care, and adds much to our previous knowledge of the distribution of the rocks of the State. Besides the general map, there are sections of the strata, and those of the associated Azoic and Paleozoic rocks are particularly interesting.

5. *New Geological Map of Wisconsin;* by I. A. LAPHAM. 1869. Milwaukee.—This Map, which has just been issued, will prove of much service to all interested in the Geology of the region of which it treats. It is on a scale of 15 miles to an inch, and gives in detail the geological features of the State, as they have been carefully worked out by Hall and Whitney, the author, and other explorers.

6. *Reliquiæ Aquitanicæ*, being contributions to the Archæology and Palæontology of Périgord and the adjoining provinces of Southern France; by E. LARTET and H. CHRISTY, edited by THOMAS RUPERT JONES, Prof. of Geology, etc., Royal Military College, Sandhurst. (London. H. Ballière.)—Parts VI and VII of this important work have been issued.

7. *Gold in Scotland.*—Gold diggings in the north of Scotland will be a surprise to many persons; but there they are, in the shire of Sutherland, and with a number of diggers who are collecting alluvium from the borders of the Holmsdale river, and washing it in the stream. The quantity hitherto collected is not great, perhaps 200*l.* worth, but the quality is described as good, and the color bright: and diggers who have worked in Australia are of opinion that when proper means are taken the yield will be something considerable.—*Athenæum, Feb.* 6.

III. BOTANY AND ZOOLOGY.

1. *Field, Forest, and Garden Botany, a simple introduction to the common plants of the United States east of the Mississippi, both w and cultivated;* by ASA GRAY. Small 8vo, pp. 386. New York: 1868. (Ivison, Phinney, Blakeman & Co.)—This work, which for the present is offered only in the same cover with Gray's First Lessons, the two together being styled "*Gray's School and Field Book of Botany,*" was promised in the preface of the fifth edition of the Manual, and its preparation was completed only a few days before the departure of the author, in September last, for Europe. It is designed to be a simple and easy introduction to Systematic Botany, as represented by the common plants, wild and cultivated, of the States east of the great river, and therefore most of the very rare or difficult species are omitted, thus gaining space for the admission of several hundred cultivated plants. The analytical keys are made very easy, and in the description of the plants technical expressions are as far as possible avoided, so that a person of ordinary intelligence, who has no claim to botanical acquirements, could with little effort trace out a flower to its proper place in the system, and would there learn something of its nature, and native country, and would perhaps find a hint or two about its mode of cultivation, as well as discover the "long name" which Linnæus, or some disciple of his, has seen fit to impose upon it.

This book will necessarily commend itself to all *amateurs* of horticulture, whether for the kitchen, flower-garden or conservatory, for there is no other work in the English language which gives so plain an account of the plants commonly (or even rarely) met with in cultivation. While the Manual will be the most useful book an American botanist can have on his table, he will always keep the Field, Forest, and Garden Botany near at hand, and the beginner in these studies will thank Dr. Gray for this little book, which fairly puts the science within the reach of the youthful, and makes Botany more a matter of every-day life than it has ever been before. D. C. E.

2. *Are Unios sensitive to light? Note by* C. A. WHITE. (Communicated for this Journal.)—Those who have studied the habits of Unios in their native element, are of course well aware of their habit of burying themselves in the mud or sand, leaving only the

posterior portion projecting, for the purpose of giving ingress and exit to the respiratory currents of water. The sensitiveness of the margins of the incurrent and excurrent orifices to the slightest touch, is also well known; but during the past summer, while collecting mollusks in one of the rivers of Central Iowa, I became convinced that those, or adjacent parts, were also keenly sensitive to light.

Unios were found numerously occupying the position referred to, plying their currents industriously through their distended orifices, but whenever my shadow in the bright sunlight came suddenly upon them, they invariably closed their orifices quickly and completely. This was repeated a great many times, and upon the same individuals, to assure myself that it was not caused by any agitation of the water, or movement of impurities in it, that might produce irritation of the parts. It was evidently the interception of the sun's rays alone that caused them so suddenly to close their orifices, yet it is worthy of remark that they did not quickly close them, if sunlight was suddenly admitted to them while respiring in the shade.

The question then arose in my mind as to the possibility that the parts were sensitive alone to the rays of heat from the sun, and not to those of light. Above the Unios was from one to two feet in depth of clear running water, rendering every thing upon the bottom distinctly visible.

Believing that the sun's rays coming directly toward any object so far beneath the surface of the water, would have its heat-rays mostly if not entirely separated from the light-rays, at or near the surface, through the absorption of these and their removal downward by the current, while nearly all the rays of light would pass on to the object with only slight refraction, I sought a place where rays of heat from sunlight, striking the surface further up the stream, would not reach the Unio to be experimented upon. This was furnished by a dense growth of trees, shading the stream completely for a considerable distance. Then placing a Unio just at the lower margin of the shade, but quite within the bright sunlight, and awaited the opening of the orifices, then quickly intercepting the sun's rays that came freely to it, by passing a screen from above downward, and again from below upward, it responded by closing its orifices as quickly as its fellows had done when my shadow passed over them in the broad open space of sunlight.

Upon the supposition that the light and heat-rays are divided at the surface of the water, as before suggested, the heat-rays must all, or very nearly all, have passed down below the Unio, by the action of the current, while the light-rays alone reached it, and their sudden interception caused it to close its orifices. Thus in this position the Unio was receiving direct rays of light from the sun, but the rays of heat that might have reached it more or less obliquely, by absorption and the action of the current, if in an open space of sunlight, were here cut off by the long shadow of the trees. Therefore no doubt is entertained that the posterior

portion of these mollusks is keenly sensitive to light, but exactly what organs are thus sensitive has not been ascertained.

Iowa City, Iowa, Dec. 21, 1868.

3. *Critical Remarks on Halcyonoid Polyps. No.* 3, by A. E. VERRILL.—In the February number of the Annals and Magazine of Natural History, p. 117, Dr. J. E. Gray has published "Notes on the Fleshy Alcyonoid Corals," in which he has made a new arrangement of the group, which he divides into 12 families and 31 genera! Most of the new genera and many of the families are founded mainly on variations in the form, mode of branching, prominence of the verrucæ, and arrangement of the cells,—characters that are notoriously unreliable among polyps, and especially liable to mislead when, as in this case, we have to depend mainly on imperfect figures and descriptions, or specimens contracted in alcohol. On this account we believe that many of the groups founded on such characters cannot be maintained, when the specimens are themselves carefully studied with reference to their internal structure.

At the present time, however, we propose merely to point out some errors of the author, mainly in reference to species described in this country.

Massarella is proposed for a group having as its type, *Sympodium coralloides* Ehr., the same species taken by Kölliker as the type of Sympodium.

Sympodium verum D. and M., which he refers to it, does not agree with the generic characters given, for in the original description we find "*calycibus semper prominulis.*" It may belong to our *Callipodium* and if so would bear the name *C. verum*, which, at present, is not very appropriate.

Sympodium Pacificum V., (erroneously quoted as "S. poriferum V.") is the type of our genus *Callipodium* (Trans. Conn. Acad., Jan., 1868).

Ojeda, adopted from D. and M., is, as we are informed by Dr. Kölliker, a *sponge.*

Lobularia is adopted from Lamarck for the most numerous group of species usually referred to Alcyonium, with *L. digitata* as type. *Lobularidæ* are characterized as having a "hard, crustaceous, smooth, external coat," and division B, including the family, as being entirely covered by polyps "to the edge of the crust or the base of the stem." But *Alcyonium carneum* Ag. and *A. rubiforme* Dana, both of which he refers to *Lobularia*, have neither of these characters. Both have a barren stalk or trunk, and (in full expansion) barren bases to the branches, the polyps being clustered at the ends, as is beautifully shown in a series of photographs, which I made last season from living and fully expanded specimens. These species agree in some states of expansion with Gray's genus *Alcyonium*, as restricted; in other cases with *Danella;* and frequently with *Amocella.* All these and many other forms of growth and modes of branching were noticed by me in *A. carneum*, while studying several hundred living specimens

last summer. There may be other characters, at present unknown, sufficient to separate *Danella* from *Alcyonium*, but the mode of growth certainly is not.

Lobularia Verrillii Gray, named from a specimen that I regarded as too imperfect to describe, and of which only the most obvious characters were mentioned incidentally, is certainly not a *Lobularia*.

Areocella is proposed as a genus including only *Alcyonium latum* Dana. This species is, as we have before stated, a true *Sarcophyton*, and in this case there is not even a difference in mode of growth, if specimens of *S. latum* be compared with those of the same size of *S. glaucum*, but the former grows to a larger size than observed specimens of the latter, and then becomes more irregular. The differences mentioned in the character of the surface and arrangement of the cells are wholly imaginary, as I have ascertained by an examination of Dana's original specimens. In each the polyps are dimorphous, like those of all other species of the genus, as stated by Kölliker. And in each the larger cells are distantly scattered over the upper surface, and surrounded by a circle of the smaller polyps, which are figured by Dana in *S. latum*, and thus is produced the appearance described by Gray in *Areocella*, "upper surface areolated, areolæ hexagonal, each surrounded by a series of small tubercles. Polypes in the centre of each areola." In *S. glaucum* and *S. agaricum* the same character exists, only the secondary polyps are smaller and less conspicuous. In both *S. latum* and *S. glaucum* the corallum consists internally of closely arranged parallel tubes of two sizes, corresponding to the cells, separated by narrow septa filled with large, roughly warted, spindle-shaped spicula, which are similar in the two species, but blunter, shorter, and stouter in the former; in *S. glaucum* ·250^{mm} to ·325 long, by ·062 to ·087 broad; in *S. latum* ·225 to ·250 long, by ·100 to ·125 broad. The surface is granulous and covered with very small, short, roughly-warted, irregular spicula, much alike in the two species.

Bellonella ? capitata Gray. For this he quotes "*Lobularia capitata* D. and M., Corall. Antilles, 21." We find no such name in the work referred to, and the reference seems inexplicable unless an error for *Xenia capitata* D. and M., p. 16, which is also quoted on p. 122 and referred to *Lobularia capitata* Gray, but here the reference is to "t. 1, fig. 22" instead of Pl. 1, fig. 1 and 2.

Loridella Gray. This name is proposed for certain species separated from *Xenia* (type, *X. umbellata*). The principal character appears to be "surface coriaceous, with imbedded fusiform, spined spicula." To this genus he refers *X. subviridis*, *X. florida*, *X. elongata*, and *X. rosea*, the last a name for Dana's species, figured as *X. cœrulea*. The *X. florida* Dana, also appears to be distinct from Lesson's species, and may take the name, *X. Danæ* V. Having examined Dana's types I cannot find any characters upon which to separate them generically from *X. umbellata*. So far as these species are concerned the characters do not agree with those given

to *Loridella* by Gray. But if they could be separated as a genus from *Xenia*, a new name is not required, since *X. florida* is the type of *Actinantha* Lesson, which should be retained in preference to a new name, and must at least include *A. florida*, *Danæ*, *elongata*, and *rosea*.

Spoggodia is separated from *Spoggodes* on account of the cells "prominent from the sides, or forming the tips of the branchlets." But *S. gigantea* V., from Hong Kong, a species not quoted by Gray, has part of the polyps clustered as in *Spoggodes*, and part placed singly on the branchlets, as in *Spoggodia*.

Lemnalia nitida Gray (*Ammothea nitida* V.). The "family," Lemnaliadæ, is said to have the "outer surface smooth, without spicules." It contains *Lemnalia* and *Verrilliana* Gray. The surface in *A. nitida* appears smoothish to the naked eye, but under the microscope it is seen to be filled with an abundance of slender, closely interlaced spicula. The interior is composed chiefly of still longer and very slender, slightly spinulose, acicula spicula, ·250^{mm} to ·500 long, by ·020 to ·025 thick The verrucæ are covered with similar spicula, mingled with few, small, stout, warty spindles, ·075 to ·125 long, by ·050 to ·075 thick. Therefore it cannot belong to this group, as defined by Gray, but agrees better with *Ammothea*, as restricted by him. Savigny's enlarged figures of the cells of *A. virescens* agree so closely with this species that, were not the verrucæ more loosely arranged, it might be thought identical. The form and mode of branching is nearly the same in each. In mode of growth it resembles *Verrilliana*, rather than *Lemnalia*. The latter seems to be near *Cœlogorgia* Val.

Verrilliana thyrsoides Gray (*Ammothea thyrsoides* Ehr.). To this species, described by Ehrenberg as destitute of external spicula, Gray unaccountably refers *Nephthya thyrsoidea* V., which was accurately described and figured as having external spicula on the prominent verrucæ. These spicula are mostly long, thorny, club-shaped spicula, ·600^{mm} to 1·00 long, by ·100 to ·200 thick; and stouter very thorny clubs ·300^{mm} to ·500 long, by ·125 to ·250 broad; and rough, sharp, three-pronged spicula ·275^{mm} to ·325 long by ·150 to ·250 broad. The thorny ends project from the surface, especially toward the summits, and give it a very rough appearance. It appears, therefore, to be closely allied to *Nephthya*, but in the latter the larger spicula are long warty, quite regular spindles, the ends not projecting.

This species may, therefore, be regarded as the type of a new genus, which we propose to call *Eunephthya*, including *E. thyrsoides* V. and *E. glomerata* V. (Lutken sp.,) from Greenland.

The latter forms an upright corallum, with a stout trunk, from all sides and to near the base of which arise short sub-conical branches, naked at their bases, like the trunk, but mostly covered with close clusters of 3 to 12, roundish, verruciform polyp-cells, which are rough exteriorly and covered with numerous very rough, thorny, club shaped spicula, ·200^{mm} to ·350 long, by ·075 to ·125 thick.

GORGONACEA.

Isidella elongata Gray=*Isis elongata* Esper.—The locality of this species is given variously by authors, as East Indies, West Indies, Mediterranean. The Museum of Yale College possesses several good specimens, agreeing perfectly with Esper's figures, which were obtained by Prof. Dana from near Naples. The locality of Esper's specimens was unknown.

Echinomuricea V., gen. nov. Type, *E. coccinea* V. (*Acanthogorgia coccinea* V., Proc. Essex Inst., iv, p. 188, Pl. 6, fig. 7). This species appears to be generically distinct from the type of *Acanthogorgia* in the structure and form of the verrucæ, and especially in the very large size and peculiar character of the spicula, which are more or less imbricated, not in whorls, branched at base, the ends much projecting, very rough, and sharp.

4. *On the Distribution of Fresh-water Fishes in the Allegheny Region of South Western Virginia*, by E. D. COPE. From the Journal of the Academy of Natural Sciences, Philadelphia, 1868, 4to. with 3 plates.—In this memoir the author gives a very interesting and complete review of the fish-faunæ of the head-waters of four distinct river basins: the James, the Roanoke, the Kanawha, and the Tennessee.

He enumerates 56 species, quite a number of which are new. Several genera are also revised, and new ones established.

Of the whole number of species observed, 14 occur in the Roanoke; 19 in the James; 27 in the Kanawha; 34 in the Holston.

Common to the four rivers,	- - - -	5	species.
" "	Roanoke and James only,	4	"
" "	James and Roanoke only,	4	"
" "	Kanawha and Holston only,	2	"
" "	James, Roanoke, and Kanawha only,	1	"

The probable origin of the resemblances and diversities among these faunæ is also discussed.

The author has entered upon a field of research which has hitherto been very little explored in America, but which will doubtless soon become of great interest to all students of Geographical Zoölogy and the origin of species. V.

5. *Catalogue of the Reptiles and Batrachians found in the vicinity of Springfield, Mass., with Notices of all other Species known to inhabit the State;* by J. A. ALLEN.—From the Proceedings of the Boston Society of Natural History, December, 1868. This is another important contribution to American Geographical Zoölogy. The list has evidently been prepared with great care, and many important notes on habits, effects of temperature, and other matters of interest are given. The whole number of true Reptiles found in the State is 24, of which 21 have been seen near Springfield. The Batrachians are represented by 21 species in the State, of which Springfield claims 19, making 45 species of both groups in the State, with 4 or 5 others that are likely to be found hereafter. V.

6. *Notes on Radiata in the Museum of Yale College, No. 6.—Review of the Corals and Polyps of the West Coast of America;* by A. E. VERRILL. (From the Transactions of the Connecticut Academy, Vol. I. New Haven: April, 1868, to February, 1869.)—This memoir, which has been issued and distributed in signatures, each bearing the date of publication, is now completed to the Order, *Actinaria.* The number of species of *Alcyonaria* enumerated is 62, of which all except 8 have been examined and mostly re-described by the author, while 26 species are here described as new. The descriptions are very elaborate and complete, particular attention having been given to the forms of the spicula, of which numerous microscopic measurements (sometimes amounting to 100 or 200) are given. These are regarded as of the utmost importance, since it is now known that the spicula afford the most reliable characters for distinguishing the genera and species. The *Alcyonaria* are accompanied by four plates, two illustrating the spicula.

The species are distributed among the following genera:

Renilla, 1; Ptilosarcus, 1; Leioptilum, 1; Stylatula, 2; Litigorgia, 16 (9 new); Eugorgia, 6 (4 new); Phycogorgia, 1; Psammogorgia, 3 (2 new); Muricea, 18 (9 new); Heterogorgia, 2; Primnoa, 1; Callipodium, new genus, 2 (1 new); Alcyonium, 2 (1 new); and six Gorgonidæ, not examined, of which the generic relations are doubtful. Several varieties are also described and named.

7. *Annual Report of the Trustees of the Museum of Comparative Zoology*, at Harvard College, in Cambridge, together with the Report of the Director, 1867. 22 pp. 8vo. 1868.—In this Report Professor Agassiz gives a brief statement of the aims, condition and wants of the Museum; and in connection with the latter observes that the Museum needs for its increase, care, and publication fund, a capital of $500,000. Professor Lesquereux, in a Report on the Fossil Plants of the Museum, makes the following remarks on

"*The Ancient Flora of America.*—First. That the floras of our ancient formations already had peculiar types, which separated from each other those of the different continents. This is even evident in the vegetation of the Coal measures. Therefore, the supposition of a continental union of Europe with America by Atlantides or other intermediate lands, is proved to be untenable.

Second. That the essential types of the old floras, of the Cretaceous and Tertiary formations have passed into our present vegetation, or are preserved to our time. The Cretaceous of America, for example, has already the Magnolias, which we find still more abundant in our Tertiary. This last formation has furnished a number of species of the genus Magnolia, nearly identical with that now existing in the United States, while the genus is totally absent in the corresponding floras of Europe. More than this: we find in our Tertiary the same predominating types marked on both sides of the Rocky Mountains. On the Atlantic slope, leaves of magnolias, of oaks, of elms, of maples and poplars, and not a trace of coniferous trees; while in California and Vancouver Island, the

red woods or Sequoia, abound in the Cretaceous and Tertiary, as they still form the predominant vegetation of the country. These few facts are mentioned only to show the importance of collections of fossil plants from every formation of our American continent, the only part of the world where questions of general significance concerning palæontological distribution can be studied with some chances of satisfactory conclusions.

IV. ASTRONOMY.

1. *Meteors in August*, 1868.—The following observations upon the night of August 9th, were made at Durham, Conn., by Prof. C. G. Rockwood, of Bowdoin College. There were two observers.

From	12h.	15m.	to	12h.	30m.	13	meteors.	From	1h.	0m.	to 1h. 15m. 5 meteors.
"		30	to		45,	7	"	"		15	to 35, 9 "
"		45	to	1h.	0,	10	"	"		35	to 2h. 0, 12 "

In all, 56 meteors, of which all but two were conformable to the usual radiant. The sky was mostly clear, and the moon shining.

2. *Le Stelle Cadenti del Periodo di Agosto, osservate in Piemonte ed in altre Contrade d'Italia nel* 1868. 72 pp., 16mo, Turin.—These accounts of observations upon the August meteors, from seventeen Italian stations, most of them continued through three or more evenings, indicate no little zeal among Italian astronomers in the department of meteoric astronomy.

3. *Error in Stanley's Logarithmic Tables.*—Mr. Chatham Willey, of Hartford, calls attention to an error in Stanley's Logarithmic Tables. It is on page 38th, where the logarithm of 30672 should be ·4867421 instead of 4864721.

V. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Convention of American Philologists.*—A Convention of American Philologists, will be held in Poughkeepsie, N. Y., commencing on Tuesday, July 27th, 1869, and continuing in session for several days. The call to this Convention is issued pursuant to a resolution passed at a preliminary meeting held in the New York University, on Nov. 13th, 1868.

Measures will be taken during the session to complete the organization of a permanent National Society for the Promotion of Philological Studies and Research in America. Papers upon different branches of Philology by distinguished American Linguists will be read and discussed. The time that may then remain to the Convention will be devoted to the discussion of the following, among other questions, relative to the position which the Study of Language should occupy in our educational system, to the best methods of Philological Instruction, and to the promotion of Philological Literature in America.

1. How much of the time in a Collegiate course of study should be given to the study of Language? 2. How much of this time should be devoted to the study of the Modern Languages? 3. Should the study of the French and German precede that of the

Latin and Greek Languages? 4. What position should be given to the study of the English Language in our Colleges and other high schools of learning? 5. What is the most efficient method of instruction in the Classical Languages? 6. What is the best system of pronouncing Latin and Greek? 7. Should the written accent be observed, in pronouncing Classical Greek? 8. What more efficient measures can be taken to preserve from destruction the Languages of the Aboriginal Indians of America?

It is important that all who design attending the Convention should be present at the first session, which will be held on Tuesday, July 27th, at 3 P. M.

All persons intending to be present at the Convention, and all who propose to prepare papers to be read, are requested to communicate notice thereof, not later than by July 1st, 1869, to the *Chairman of the Committee on Organization*, Prof. GEO. F. COMFORT, (care of Harper & Bros.,) Franklin Square, New York.

The call to the Convention is signed by the leading men of the country in the departments of Philology, and the Ancient and Modern Languages.

2. *Gynæcological Society, of Boston.*—A Gynæcological Society has recently been instituted at Boston, having for its objects the advancement of Gynæcic Science and Art, and their due recognition both in Boston and throughout the country. The officers of the Society for the year 1869–70, are Winslow Lewis, President; Horatio R. Storer, Secretary; George H. Bixby, Treasurer.

OBITUARY.

CARL FRIEDRICH PHILIPP VON MARTIUS.—This eminent botanist died at his home in Munich, December 13th, 1868, in the 75th year of his age. He was born at Erlangen in Bavaria, April 17th, 1794.

His father, Dr. Ernest Wilhelm Martius, was distinguished in his day as the author of several botanical and other scientific works, and was one of the founders of the Ratisbon Botanical Society. He died as recently as 1849 in his 94th year; his last work "Memories of a Ninety Years Life," contains many genial pictures of social life in Germany during that eventful period. But the ancestors of von Martius were eminent in science much earlier than this. He used to show his friends the busts of two men, both famous in their day for their knowledge and from whom he traced his descent, one by his father's, the other by his mother's side. The one was Galeotus Martius, a celebrated philosopher, philologist and astrologer of four centuries ago. The other was the scarcely less famous astrologer, Seni.

Carl Martius pursued his studies at the Gymnasium and University at Erlangen, under the direction of his father and his father's friends. He was the botanical pupil of Schreber, and to him he was doubtless indebted for a careful training in the rudiments of the science he was destined to so greatly advance. But his studies were of a wider range, and he prosecuted them all with enthusiastic devotion. He studied zoology under Goldfuss, chemistry under Hildebrand, philology under Harless, and philosophy under

Mehmes and Vogel. He had as a fellow pupil Nees von Esenbeck, and later they prosecuted together their studies at the house of the elder von Esenbeck, at Wurzburg. He studied medicine at the University at Erlangen, graduated Doctor of Medicine, and commenced the practice of that profession in his native town. In his brief practice he was eminently successful, but botanical pursuits were more congenial to his tastes, and he published his first botanical work in 1814, when but twenty years old. He was already collecting the materials for a more important one on the Cryptogamic Flora of Erlangen, which appeared three years later, 1817.

Upon Schreber's death, his herbarium was purchased by the Bavarian Academy, at Munich, and when Professor Schrank of that city came to Erlangen to remove it, he made the acquaintance of young Martius and induced him to come to Munich, where he became a pupil of the Academy, and in 1816 he was appointed to an office in the Botanic Garden, acting indeed as director for Schrank whose age interfered with those duties.

Maximilian, King of Bavaria, was interested in Botany and in his visits to the Botanic Garden made the acquaintance of Martius, and the impression was so favorable that the King selected him, with Dr. Spix the zoologist, to join as *savants* the embassy that was to accompany the young Bavarian princess destined to be the Empress of Brazil. This decided his fortune and linked his name imperishably with that great empire. The plan of the expedition was prepared by the Bavarian Academy, and they sailed in an Austrian frigate from Trieste, April 10th, 1817.

Our space will not permit of any extended notice of this expedition, nor even an enumeration of its fertile results. They penetrated into Brazil, and traversed the valley of the Amazon to Peru, a distance of over 4,000 miles, much of it through an untrodden region. They were spared fatal accident, but their rich results were only won through the fatigues, hardships, and dangers incident to such exploration. In a little church at Santarem, at the junction of the Tapajoz with the Amazon, there is a full length crucifix presented by von Martius, and beneath it a simple inscription telling that his life had been mercifully preserved when shipwrecked near there in 1819. They were prostrated by malarial fevers, annoyed by wild beasts, and in danger from treacherous natives.

They returned in 1820 with collections amounting to 3,500 species of animals, 6,500 species of plants, and a vast amount of material relating to the ethnology, philology and history of the region. The exposures and fatigues of this expedition so undermined the health of Dr. Spix that he survived his return but a few years, leaving the burden of publishing the vast amount of material they had collected upon von Martius. The narrative was published in three quarto volumes with folio atlas, entitled, "Reise in Brasilien," Munich, 1824–31.

The first department of the collection worked up was the Palms, and the first part of his "Genera et Species Plantarum" was pub-

lished in 1823. He commenced with the palms of Brazil, but ultimately extended his investigations to the whole order. This labor continued through twenty-seven years, and the magnificent work was completed in 1850, in three large folio volumes, containing 245 plates, all finely executed and some of them exquisitely finished landscapes, exhibiting the habits of the species in their native localities. He published several smaller works on the palms, but his great work will ever remain classical. As an illustration of its scope, Humboldt knew less than a hundred species of this order; the work of von Martius embraces 582 species.

On a similarly magnificent scale was his "Nova Genera et Species Plantarum Brasiliensium," 1824 to 1832, folio, with 300 colored plates, and his "Icones Plantarum Cryptogamicarum quas per Brasiliam collegit," Munich, 1828–34, folio, with 76 colored plates.

In 1829 he began the publication of his great work, "Flora Brasiliensis," in folio, and for forty years, up to the time of his death, he labored upon this, and left it unfinished. Some portions of this are entirely his own work, in others he acted as editor, calling to his assistance some of the most distinguished botanists of the day. It will probably be completed in a series of monographs of the remaining orders, by other hands. In this work are already described nearly 8,000 species, illustrated with about a thousand folio plates.

He extensively investigated the medicinal uses of plants, and published several works on this department of botany, and also, to a less extent the bearings of his favorite science on Agriculture. Among his works is an essay on the Potato Rot, (Munich, 1843).

We will not attempt an enumeration of his other contributions to botanical literature, which extend to a very long list, and reach nearly every branch of the science.

He was Director of the Botanic Garden at Munich for about forty years, and under his direction it had perhaps the richest collection of species of living palms in Europe.

Von Martius was not only a student and traveller, but also eminently a collector. His private herbarium amounted to over 50,000 species; in the department of palms it was by far the richest extant. He was long anxious that this herbarium should ultimately come to America. He often expressed his wish to the writer, that if it was not purchased by Brazil, he would prefer to have it come to the United States. His library was large and in pre-Linnean works he considered it absolutely complete. It was also especially rich in botanical manuscripts and original drawings of plants.

From his youth, von Martius had a great fondness for linguistic studies, and he had a wonderful command of language. The Latin used in the systematic descriptions in modern botanical works, can hardly be called classical, yet his command of this language is exhibited by the elegant and eloquent dissertations which may be found in various of his works. He often used this language in his correspondence, and many of his letters, especially to his intimate friends, are classical in their purity and style. This fondness for

linguistic study showed itself throughout his life. In Brazil he paid much attention to the language of the country and he published several works upon the subject, the last of which, "Beiträge zur Ethnographie und Sprachenkunde Amerika's zumal Braziliens," (Munich, 1867, 2 vols. 8vo,) is extensive and is said to indicate great learning in this branch of knowledge. He took a deep interest in the philology and ethnology of the Indian tribes of North America, and during his long life he accumulated an immense mass of facts relating to these subjects. In his last letter to the writer, he asked for "vocabularies" and "skulls" of our western Indians.

He was for many years Secretary to the Mathematico-physical section of the Munich Academy, and in this office delivered many orations on the decease of illustrious members of the Academy. These were collected into a volume which contains many eloquent tributes to the memory of his eminent friends. In connection with this office he carried on a voluminous correspondence in various languages, a position in which his extensive linguistic knowledge was practically available.

Any notice, however short, of this good man would be incomplete if it did not allude to his personal worth and social qualities. In form, he was a small man, of slight figure, but indicative of great powers of endurance. He had a peculiarly animated countenance and bright eye. He delighted in the society of his friends, was fond of amusements, and his childlike simplicity was truly charming. His pleasant home in Karlstrasse was the resort of the cultivated, who found there the old style hospitality, and his receptions retained the genial flavor of German social life in spite of modern innovations. The annual festival commemorating his return from Brazil, the equally genial birthday celebrations were never forgotten, and he entered into their pleasures with the zest of a child.

Perhaps the recreations derived from such home pleasures preserved his strength so well, for his intellectual labors ceased only with his life. He was passionately fond of music and played the violin with rare skill and taste, and he indulged in this even to his later years. His characteristic love for collecting showed itself even here, for he possessed a valuable collection of rare old violins.

We cannot here attempt to enumerate the various titles he held, a mere list would occupy several pages of this Journal; and the "decorations" bestowed upon him were also numerous.

He died quite suddenly from an attack of lung fever. He was buried with honors, a procession of torch bearers each with a palm branch followed him to the cemetery, where many distinguished men assembled to do honor to his memory; the hymns at the grave, were sung by the students of the University where he had long been an honored and beloved officer. W. H. B.

John Cassin.—This eminent ornithologist died in Philadelphia, on Sunday, January 10th, in the fifty-seventh year of his age. We cite the following from a tribute to his memory by Dr. T. M. Brewer, in the Proceedings of the Boston Society of Natural History, 1869, p. 245.

John Cassin was born of Quaker parentage, in Chester, Pa., Sept. 6th, 1813. In 1834, at the age of twenty-one, he took up his abode in Philadelphia, where he has ever since resided. In his earlier life he engaged in mercantile pursuits, and afterwards, for several years, held important positions under the national government. At the death of Mr. Bowen, the principal engraver of Philadelphia, Mr. Cassin assumed the management of the establishment, which he continued until his death. All the reports of explorations and surveys issued by our government have been largely indebted to him for the excellence of their illustrations.

For more than thirty years Mr. Cassin has devoted all the leisure hours he could take from the requirements of his business to the study of ornithology. Privileged to reside in Philadelphia among the kindred spirits that compose its Academy, yet more privileged in having access to its wealth of ornithological specimens,—probably the greatest in the world,—and to its even greater wealth in scientific works, where is to be found, procured by the munificence of his friend, the late Dr. Wilson, every known publication of any value on the subject of ornithology—with all these privileges no one could well have enjoyed greater advantages for pursuing his favorite study, and certainly no one could have better improved such rare opportunities.

With a full appreciation of all that I aver, I claim for my lamented friend, that as a general ornithologist, especially in regard to his knowledge of the forms of the Old World, Mr. Cassin had no superior either in this country or elsewhere—it may even be doubted if he had an equal. By long and diligent study, by the most thorough investigations, and by the most careful researches into the authorities, with a patient perseverance that nothing could discourage, he rendered himself a complete master of the science. So perfectly familiar was he with the forms of the Old World, that he investigated their classification, established new genera and described new species as readily in Africa as in America, and the savans of Europe have accepted with deference his decisions.

Mr. Cassin has been for many years an active member of the Philadelphia Academy of Natural Sciences. His valuable contributions have enriched the pages of its Journal, and added a world-wide reputation to its Proceedings. His activity and zeal in the cause of science have aided to draw around that institution munificent patrons, as well as distinguished co-laborers, under whose influence, and by whose means, the Academy has risen to the highest rank as a well endowed and honorable school of the natural sciences. Time would hardly serve me to read even the titles of the fifty-six separate and distinct papers, descriptive, analytic and synoptical, given in the Catalogue of the Royal Society of London, as contributed from time to time by Mr. Cassin to the Proceedings of the Academy, and which constitute only a portion of his valuable contributions to ornithological science. His more elaborate publications have been his Birds of California and Texas, an octavo volume, giving descriptions and colored engravings of fifty species of birds not enumerated by Audubon; the Ornithology of the

United States Exploring Expedition under Lieut. Wilkes; the Ornithology of the Japan Expedition; the Ornithology of Gilliss's Astronomical Expedition to Chili; and the portions of the Ornithology of the Pacific Railroad Explorations and Surveys relating to the Rapacious and the Wading Birds.

His communications and all his contributions to science are distinguished by their careful research, their thoroughness, and their unfailing accuracy—an accuracy that was ever above reproach, and as it seems even beyond criticism.

Nor was it alone as a closet naturalist that Mr. Cassin was distinguished. He was also an ardent lover of nature, and a close observer of living birds, both in their wild wood haunts, and under the open sky. I am indebted to him for much valuable information, derived from his observations upon the habits of various birds; and it was to aid from his unequalled knowledge that we have looked forward for the correct classification of the collection of our Society. But alas, that once ever open volume, so abounding in its wealth of knowledge, is now forever closed to us on earth, and with his fleeting spirit has passed from us that seemingly exhaustless treasury of science to which we never appealed in vain.

As a man, our departed friend was of unswerving uprightness, warm-hearted, cordial and sincere, firm and abiding in his friendship, and only a foe to whatever was wrong, ungenerous or illiberal—possessed of strong, fervent and generous impulses, and frank and outspoken in the expression of his opinions. Decided in his own views, he was still ever tolerant and liberal towards those who differed from him.

In a word, whether we regard Mr. Cassin as the naturalist, whose scientific achievements had placed him in the front ranks of the votaries of science; as the man of business, and the honored head of a house which was devoting all its energies and the highest artistic skill to the illustration of science; or as the ever sympathizing and congenial friend,—his death in the full prime and vigor of life, and in the very midst of his transcendent usefulness, can only be received as one of those inscrutable deprivations which, while we must accept them in humble faith, we cannot but deplore.

Prof. Theodore Strong.—The able mathematician, Theodore Strong, died at his residence at New Brunswick, N. J., Feb. 1st, at the age of 79. Having graduated at Yale College in 1812, he immediately after entered on the duties of tutor, and subsequently of Professor of Mathematics at Hamilton College, Clinton, N. Y., where he remained until 1827. He then became connected with Rutgers College, at New Brunswick, New Jersey, and continued in his Professorship there until 1862. He was a man of great excellence of character, positive in his opinions, frank and communicative, and enthusiastic in his mathematical studies. He published various mathematical papers in the first series of this Journal, and an Algebra of high order in 1860; and a Treatise by him on the Differential and Integral Calculus was in press when he died.

JAMES DAVID FORBES.—The Scotch physicist, James D. Forbes, died at Clifton on the 31st of December, in the 60th year of his age. Ill-health had led him to retire, a few months before his death, from the Principalship of the United Colleges of St. Salvador and St. Leonard, at St. Andrews. He was educated in the University of Edinburgh, and there he became Professor of Natural Philosophy in 1833. His memoirs on physical subjects, and especially his works on Glaciers, have given his name a world-wide reputation.

DR. HÖRNES.—Dr. Moriz Hörnes, director of the Austrian Imperial Mineralogical Cabinet, died at Vienna, Nov. 4th, 1868, aged 54 years. He is well known in scientific literature, by his researches on the mollusca of the Vienna tertiary, and various papers on mineralogy and paleontology. As director of the finest mineralogical collection of the world, he exercised the greatest liberality in offering facilities to others pursuing investigations in mineralogy; and so devoted was he to the interests of the cabinet, that during the late financial embarrassments of Austria, when the income of the museum was cut down, he supplied from his own narrow means what was needed to promote the increase of the collection. He was a man of most genial manners, and noble, earnest scientific spirit; his sudden death in the prime of life, is a great loss to science.

VI. MISCELLANEOUS BIBLIOGRAPHY.

1. *Handbook of Chemistry, for School and Home use;* by W. J. ROLFE and J. A. GILLET, Teachers in the High School, Cambridge, Mass. 12mo, pp. viii, 205. Boston, 1869. (Woolworth, Ainsworth & Co.).—We have already noticed the volume of the "Cambridge course of Elementary Physics" which treats of chemistry (this Journal, Jan. 1868). The present "Handbook" is designed for those teachers who desire "something easier (!) and briefer" than that. After a few general experimental demonstrations, given to familiarize the student with chemical changes, the more important elements are taken up *seriatim* and quite satisfactorily treated. Three practical sections, on the "Chemistry of the Atmosphere," on "Destructive distillation and its products," and on "Fermentation," are then introduced, and the volume closes with an Appendix on Chemical Philosophy—largely taken, as the author states, from Cooke's First Principles of Chemical Philosophy, edition of 1868—and Questions for Review and Examination. We notice that the old fiction of "Affinity" is retained, and that it is rather loosely stated (p. 45) that "Affinity changes the properties of the substances which it combines." Olefiant gas H_4C_2 is written twice (pp. 134 and 149) H_2C, and aerated bread is said (p. 159) to be made by kneading the dough with water charged with carbonic acid gas. The old and now entirely false dogma that "as yet, we are ignorant of the mode of arrangement" of the atoms in the molecule (p. 162) should, since Kekulé's masterly researches on the Aromatic Series, be expunged from our chemistries.

On the whole, the book is a valuable addition to our meagre collection of text-books on the new system, and we commend it to the notice of teachers.

2. *Van Nostrand's Eclectic Engineering Magazine.* 80 to 96 pp. large 8vo. Monthly: vol. I, No. 1. Jan. 1, 1869.—This periodical meets a want which must have been generally felt by American Engineers, of a magazine that should furnish abstracts of important investigations, and of the expositions of new projects, valuable experimental results, and signal achievements in works of construction, that may appear in the Engineering serial publications of Europe and America. It is designed to provide the American Engineer with the means of readily informing himself with regard to the "current fact and opinion" in his profession both at home and abroad; and is calculated to prove a valuable aid in this way, and by furnishing an index to important discussions, even to those who may have the leisure to consult the original publications.

The work of selection and condensation from other Journals, and of editing, generally, this new Magazine, is under the able direction of Mr. A. L. Holley, the well known author of valuable Engineering works, and practical Engineer. Two numbers have been issued, and they must be pronounced a decided success. They afford good indication that the design set forth in the Publisher's Prospectus of presenting "within limits of space and cost that all can afford," the cream of all the principal Journals of Practical Science, will be satisfactorily realized.

3. *Annual Report of the Board of Regents of the Smithsonian Institution*, showing the operations, expenditures and condition of the Institution for the year 1867. 506 pp. 8vo. Prof. Henry adds very greatly to the scientific value of his reports, by the various memoirs which are appended. In the present volume there are biographical sketches of Legendre, Peltier, Faraday and the Jussieus; a paper on the natural history of organized bodies, by M. Marey; on the electrical currents of the earth, by C. Matteucci; on Man as the cotemporary of the Mammoth and the Reindeer in Middle Europe, from the German "Aus der Natur;" Photo-chemistry, by Jamin; on Traces of the early mental condition of man, by E. B. Taylor; besides various other articles in Ethnology, Geography, Zoology, Meteorology, Physics, etc.

4. *The Manufacturer and Builder:* a Practical Journal of Industrial Progress. Western & Company, Publishers, 37 Park Row, New York. January, March, 1869. This new serial commenced with the current year, appears monthly, at the very low price of $1.50 for the year. It is beautifully printed in a large quarto form, of three columns, on excellent paper, and will prove to be an important addition to the resources of the large class of practical men, to whose interests it is exclusively devoted. Its success is already assured by a very large circulation.

5. *Blank Maps for marking the distribution of Plants and Animals.*—The Boston Society of Natural History has issued blank maps, designed for marking, by pencil or water-colors, the limits

of known distribution of given species of animals or plants over the area delineated. Since, for such a purpose, the student needs a larger or smaller number of charts, according as his field of research is wider or narrower, they have been prepared, a circular states, as cheaply as possible, consistent with entire accuracy. They have been purposely printed on thin paper, which will take water-colors, and will be furnished in any number at the cost price of a very large edition, viz: $6.70 per hundred. Copies are ready for delivery, and can be obtained by forwarding the necessary sum to Samuel H. Scudder, the Librarian of the Society.

6. *Le Naturaliste Canadien.*—A popular scientific monthly in French, of the above title, has been commenced at Quebec under the editorial charge of M. L'Abbe Provancher, curé de Portneuf. Each number contains 24 pages 8vo, and the first was published in December last.

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On the Origin of Genera. By Edward D. Cope. A. M. 80 pp. octavo, 1869. From the Proceedings of the Acad. Nat. Sci. Philadelphia.

Proceedings of the Essex Institute, Salem, Mass. Vol. v, No. 8.—p. 188, Progress of Sacred Music in New England; *A. C. Goodell, Jr.*—p. 191, American Lichenography; *H. Willey.*—Communications.—p. 273, List of the Birds of New England; *E Coues.*—p. 315, Synopsis of the Polyps and Corals of the North Pacific Exploring Expedition, Part 4, Actinaria; *A. E. Verrill.*

Annals Lyc. Nat. Hist. of New York. Vol. ix, Nos. 1–4, April, 1868—p. 1, Notes on the Later Extinct Floras of North America, with Descriptions of some New Species of Fossil Plants from the Cretaceous and Tertiary Strata; *J. S. Newberry.*—p. 76, Notes on certain Terrestrial Mollusca, with Descriptions of New Species; *T. Bland.*—p. 86, Catalogue of the Birds found in Costa Rica; *G. N. Lawrence.*

Proceedings of the American Philosophical Soc. Vol. x, No. 80, Oct. to Dec., 1868.—p. 445, Notes on the Origin of Bitumens, together with Experiments upon the formation of Asphaltum; *S. F. Peckham.*—p. 463, Notes on the Geology of Wyoming and Colorado Territories; *F. V. Hayden.*—p. 481, Obituary Notice of W. P. Foulke; *J. P. Lesley.*—p. 513, Obituary Notice of J. R. Ingersoll; *G. Sharswood.*—p. 522, Indian Figures cut on rocks; *T. C. Porter.*—p. 523, Tidal Rainfall at Philadelphia; *P. E. Chase.*—p. 539, Observations on the Meteors of Nov. 14; *P. E. Chase.*—p. 541, On the Shower of November Meteors; *D. Kirkwood.*—p. 543, Notes on the D'Orbinay Papyrus; *J. P. Lesley.*—p. 561, Classified Catalogue of the Harris Collection in Alexandria, Egypt; *J. P. Lesley.*

Proceedings Bost. Soc. Nat. Hist. Vol. xii.—p. 162, Description of a New Species of Thecla; *C. P. Whitney* —p. 165, Descriptions of American Bees, No. 1, Andrenidæ; *E. T. Cresson.*—p. 171, Catalogue of the Reptiles and Batrachians found in the Vicinity of Springfield, Mass.; *J. A. Allen.*—p. 205, Some Observations on the Fauna of Madeira; *F. H. Brown.*—p. 214, Sketch of the Life of Dr. Ebenezer Emmons; *J. B. Perrey.*—p. 219, Indian Relics at Swanton, Vt.; *J. B. Perrey.*—p. 222, Geographical Distribution of the Birds of the Department of Vera Cruz; *F. Sumichrast.*—225, Vision of Fishes and Amphibians; *B. J. Jeffries.*—p. 228, Arrangement of the families of Orthoptera; *S. H. Scudder.*—p. 235, On the Landslides in the Vicinity of Portland, Me.; *E. S. Morse.*—p. 244, Obituary of John Cassin; *T. M. Brewer.*—p. 248, Additional Notes on the Reptiles and Batrachians of Springfield, Mass.; *J. A. Allen.*—p. 250, On the Reptilian Orders, Pythonomorpha and Streptosauria; *E. D. Cope.*